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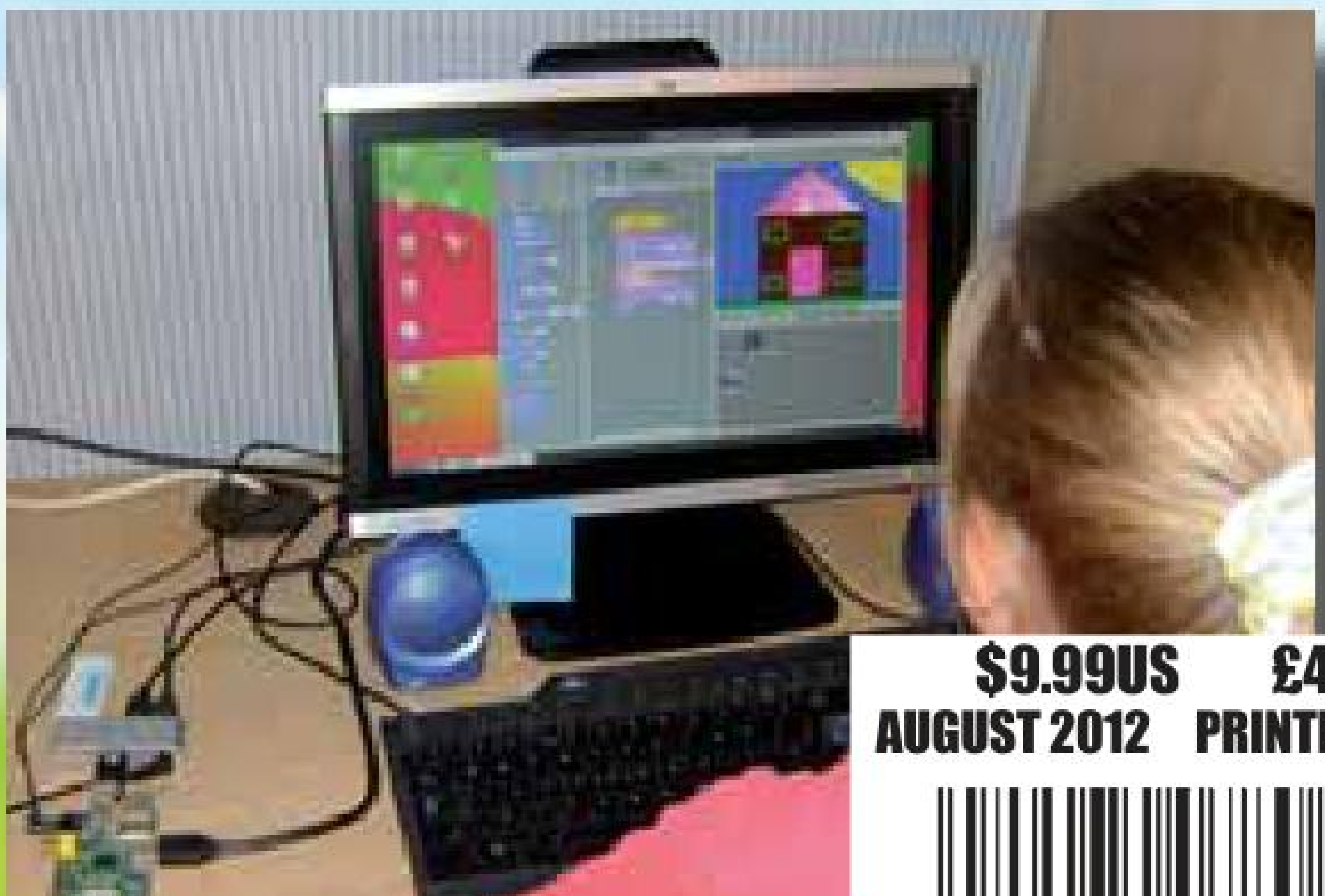

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CIRCUIT SURGERY, READOUT, TECHNO TALK

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- 2ND PRIZE A Raspberry Pi Model-B Single Board Computer
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Microchip PICkit 3 Debug Express

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• PROJECTS • THEORY •
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VOL. 41. No 8 August 2012

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Raspberry Pi

What is the Raspberry Pi?

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Our September 2012 issue will be published on Thursday 2 August 2012, see page 80 for details.

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PIC & ATMEL Programmers

We have a wide range of low cost PIC and ATMEL Programmers. Complete range and documentation available from our web site.

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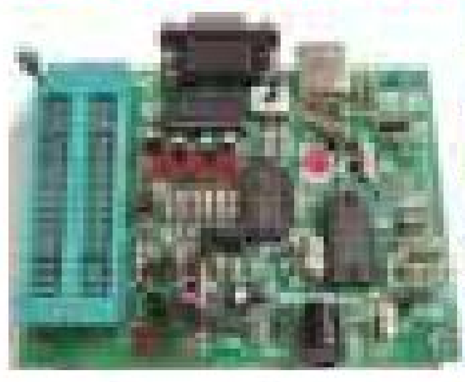
40-pin Wide ZIF socket (ZIF40W) £14.95
18Vdc Power supply (PSU121) £22.95
Leads: Parallel (LDC136) £3.95 / Serial (LDC441) £3.95 / USB (LDC644) £2.95

USB & Serial Port PIC Programmer

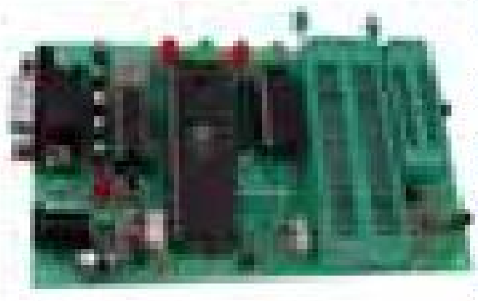


USB/Serial connection. Header cable for ICSP. Free Windows XP software. See website for PICs supported. ZIF Socket and USB lead extra. 18Vdc.
Kit Order Code: 3149EKT - **£49.95**
Assembled Order Code: AS3149E - **£64.95**
Assembled with ZIF socket Order Code: AS3149EZIF - **£74.95**

USB Flash PIC Programmer

USB PIC programmer for a wide range of Flash devices—see website for details. Free Windows Software. ZIF Socket and USB lead not included. Powered via USB port - no external power supply required.
Assembled with ZIF socket Order Code: AS3150ZIF - **£64.95**

ATMEL 89xxxx Programmer



Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. Supply: 16Vdc.
Kit Order Code: 3123KT - **£28.95**
Assembled Order Code: AS3123 - **£39.95**

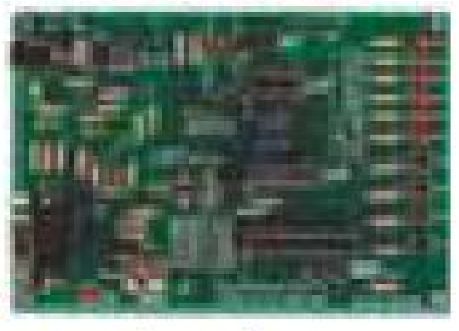
Introduction to PIC Programming

Go from complete beginner to burning a PIC and writing code in no time! Includes 49 page step-by-step PDF Tutorial Manual, Programming Hardware (with LED test section), Win 3.11—XP Programming Software (Program, Read, Verify & Erase), and 1rewritable PIC16F84A that you can use with different code (4 detailed examples provided for you to learn from). PC parallel port.
Kit Order Code: 3081KT - **£16.95**
Assembled Order Code: AS3081 - **£24.95**

PIC Programmer Board

Low cost PIC programmer board supporting a wide range of Microchip® PIC™ microcontrollers. Requires PC serial port. Windows interface supplied.
Kit Order Code: K8076KT - **£34.95**

PIC Programmer & Experimenter Board



The PIC Programmer & Experimenter Board with test buttons and LED indicators to carry out educational experiments, such as the supplied programming examples. Includes a 16F627 Flash Microcontroller that can be reprogrammed up to 1000 times for experimenting at will. Software to compile and program your source code is included.
Kit Order Code: K8048KT - **£34.95**
Assembled Order Code: VM111 - **£44.95**

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code PSU446 £8.95

USB Experiment Interface Board

5 digital input channels and 8 digital output channels plus two analogue inputs and two analogue outputs with 8 bit resolution.
Kit Order Code: K8055NKT - **£29.95**
Assembled Order Code: VM110N - **£43.95**

Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED 's. Rx: PCB 77x85mm, 12Vdc/6mA (standby). Two *& Ten Channel versions also available.*
Kit Order Code: 3180KT - **£54.95**
Assembled Order Code: AS3180 - **£64.95**

Computer Temperature Data Logger

Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.
Kit Order Code: 3145KT - **£19.95**
Assembled Order Code: AS3145 - **£26.95**
Additional DS1820 Sensors - **£4.95 each**

Remote Control Via GSM Mobile Phone

Place next to a mobile phone (not included). Allows toggle or auto-timer control of 3A mains rated output relay from any location with GSM coverage.
Kit Order Code: MK160KT - **£11.95**

Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

4-Ch DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12Vdc.
Kit Order Code: 3140KT - **£79.95**
Assembled Order Code: AS3140 - **£94.95**

8-Ch Serial Port Isolated I/O Relay Module

Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130x100x30mm. Power: 12Vdc/500mA.
Kit Order Code: 3108KT - **£74.95**
Assembled Order Code: AS3108 - **£89.95**

Infrared RC 12–Channel Relay Board

Control 12 onboard relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12Vdc/0.5A
Kit Order Code: 3142KT - **£64.95**
Assembled Order Code: AS3142 - **£74.95**

Audio DTMF Decoder and Display

Detect DTMF tones from tape recorders, receivers, two-way radios, etc using the built-in mic *or* direct from the phone line. Characters are displayed on a 16 character display as they are received and up to 32 numbers can be displayed by scrolling the display. All data written to the LCD is also sent to a serial output for connection to a computer. Supply: 9-12V DC (Order Code PSU303). Main PCB: 55x95mm.
Kit Order Code: 3153KT - **£37.95**
Assembled Order Code: AS3153 - **£49.95**

3x5Amp RGB LED Controller with RS232

3 independent high power channels. Preprogrammed or user-editable light sequences. Standalone option and 2-wire serial interface for microcontroller or PC communication with simple command set. Suitable for common anode RGB LED strips, LEDs and incandescent bulbs. 56 x 39 x 20mm. 12A total max. Supply: 12Vdc.
Kit Order Code: 8191KT - **£29.95**
Assembled Order Code: AS8191 - **£39.95**

Hot New Products!

Here are a few of the most recent products added to our range. See website or join our email Newsletter for all the latest news.

4-Channel Serial Port Temperature Monitor & Controller Relay Board

4 channel computer serial port temperature monitor and relay controller with four inputs for Dallas DS18S20 or DS18B20 digital thermometer sensors (£3.95 each). Four 5A rated relay channels provide output control. Relays are independent of sensor channels, allowing flexibility to setup the linkage in any way you choose. Commands for reading temperature and relay control sent via the RS232 interface using simple text strings. Control using a simple terminal / comms program (Windows HyperTerminal) or our free Windows application software.
Kit Order Code: 3190KT - **£84.95**
Assembled Order Code: AS3190 - **£99.95**

40 Second Message Recorder

Feature packed non-volatile 40 second multi-message sound recorder module using a high quality Winbond sound recorder IC. Standalone operation using just six onboard buttons or use onboard SPI interface. Record using built-in microphone or external line in. 8-24 Vdc operation. Just change one resistor for different recording duration/sound quality. sampling frequency 4-12 kHz.
Kit Order Code: 3188KT - **£29.95**
Assembled Order Code: AS3188 - **£37.95**
120 second version also available

Bipolar Stepper Motor Chopper Driver

Get better performance from your stepper motors with this dual full bridge motor driver based on SGS Thompson chips L297 & L298. Motor current for each phase set using on-board potentiometer. Rated to handle motor winding currents up to 2 Amps per phase. Operates on 9-36Vdc supply voltage. Provides all basic motor controls including full or half stepping of bipolar steppers and direction control. Allows multiple driver synchronisation. Perfect for desktop CNC applications.
Kit Order Code: 3187KT - **£39.95**
Assembled Order Code: AS3187 - **£49.95**

Video Signal Cleaner

Digitally cleans the video signal and removes unwanted distortion in video signal. In addition it stabilises picture quality and luminance fluctuations. You will also benefit from improved picture quality on LCD monitors or projectors.
Kit Order Code: K8036KT - **£29.95**
Assembled Order Code: VM106 - **£44.95**

Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix).

Motor Speed Controllers

Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full details.

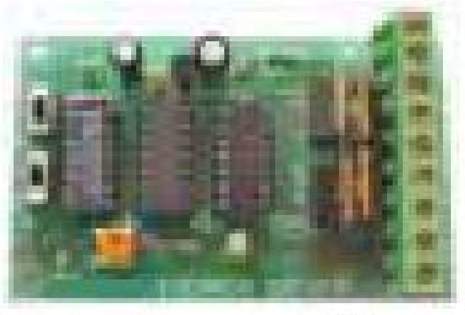
DC Motor Speed Controller (100V/7.5A)

Control the speed of almost any common DC motor rated up to 100V/7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied. Dimensions (mm): 60Wx100Lx60H.
Kit Order Code: 3067KT - **£19.95**
Assembled Order Code: AS3067 - **£27.95**

Bidirectional DC Motor Speed Controller

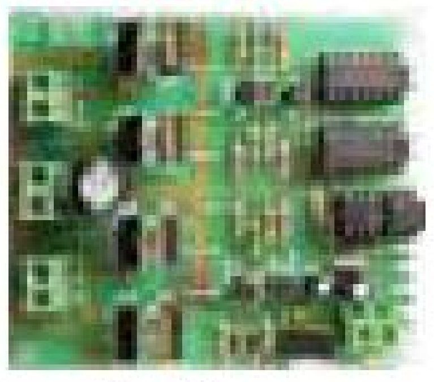
Control the speed of most common DC motors (rated up to 32Vdc/10A) in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections.
Kit Order Code: 3166v2KT - **£23.95**
Assembled Order Code: AS3166v2 - **£33.95**

Computer Controlled / Standalone Unipolar Stepper Motor Driver



Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six 3179 driver boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm.
Kit Order Code: 3179KT - **£17.95**
Assembled Order Code: AS3179 - **£24.95**

Computer Controlled Bi-Polar Stepper Motor Driver



Drive any 5-50Vdc, 5 Amp bi-polar stepper motor using externally supplied 5V levels for STEP and DIRECTION control. Opto-isolated inputs make it ideal for CNC applications using a PC running suitable software. Board supply: 8-30Vdc. PCB: 75x85mm.
Kit Order Code: 3158KT - **£24.95**
Assembled Order Code: AS3158 - **£34.95**

AC Motor Speed Controller (600W)

Reliable and simple to install project that allows you to adjust the speed of an electric drill or 230V AC single phase induction motor rated up to 600 Watts. Simply turn the potentiometer to adjust the motors RPM. PCB: 48x65mm. Not suitable for use with brushless AC motors.
Kit Order Code: 1074KT - **£15.95**
Assembled Order Code: AS1074 - **£23.95**

See www.quasarelectronics.com for lots more DC, AC and Stepper motor drivers

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Order Code EPL500 - **£179.95**
Also available: 30-in-1 **£17.95**, 50-in-1 **£29.95**, 75-in-1 **£39.95** £130-in-1 **£49.95** & 300-in-1 **£79.95** (see website for details)

Tools & Test Equipment

We stock an extensive range of soldering tools, test equipment, power supplies, inverters & much more - please visit website to see our full range of products.

Advanced Personal Scope 2 x 240MS/s

Features 2 input channels - high contrast LCD with white backlight - full auto set-up for volt/div and time/div - recorder roll mode, up to 170h per screen - trigger mode: run - normal - once - roll ... - adjustable trigger level and slope and much more.
Order Code: APS230 - ~~£499.95~~ **£394.95**

Personal Scope 10MS/s

The Personal Scope is not a graphical multimeter but a complete portable oscilloscope at the size and the cost of a good multimeter. Its high sensitivity - down to 0.1mV/div - and extended scope functions make this unit ideal for hobby, service, automotive and development purposes. Because of its exceptional value for money, the Personal Scope is well suited for educational use.
Order Code: HPS10 - ~~£189.95~~ **£139.95**

See website for more super deals!

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240V 10A Deluxe Motor Speed Controller Kit

Cat. KC-5478

The deluxe motor speed controller kit allows the speed of a 240VAC motor to be controlled smoothly from near zero to full speed. The advanced design provides improved speed regulation & low speed operation. Also features soft-start, interferences suppression, fuse protection and over-current protection. Kit supplied with all parts including pre-cut metal case.

£36.25*

NOTE: Requires UK mains socket or adaptor

Featured this Month

Simple 1.5A Switching Regulator Kit

Cat. KC-5508

Outputs 1.2 to 20V from a higher voltage DC supply at currents up to 1.5A. It is small, efficient and with many features including a very low drop-out voltage, little heat generation, electronic shutdown, soft start, thermal, overload and short circuit protection. Kit supplied with PCB, pre-soldered surface mounted components and all PCB mount components.

- PCB: 49.5 x 34mm

£14.50*

PIC Based Water Tank Level Meter Kit

Cat. KC-5460

£39.50*

This PIC-based unit uses a pressure sensor to monitor water level and will display tank level via an RGB LED at the press of a button. The kit can be expanded to include and optional wireless remote display panel that can monitor up to ten separate tanks (KC-5461 available separately) or you can add a wireless remote controlled mains power switch (KC-5462 available separately) to control remote water pumps.

- Kit includes electronic components, case, screen printed PCB and pressure sensor

Featured in EPE May 2010

Telemetry Base Station Kit for Water Tank Level Meter

Cat. KC-5461

£31.00*

This Base Station is intended for use with the telemetry version of the KC-5460 water tank level meter. It has an inbuilt 433MHz wireless receiver and can handle data transmissions from up to 10 level meters and display the results on a 2-line 32-character LCD module. Includes transmitter upgrade for one tank level meter.
Remote electric pump control option available.

Featured in EPE May 2010

Theramin Synthesiser Kit

Cat. KC-5295

£21.75*

Hundreds Sold!

This modern Theremin synthesiser produces eerie science fiction movie sounds when you move your hand between a metal plate and antenna.
Features built-in loudspeaker for practice sessions and line output.

- Kit includes case, silk screened front panel, metal plate, antenna, speaker and all electronic components
- 9-12VDC plugpack required **(use MP-3146 £6.25)**

45 Second Voice Recorder Kit

Cat. KC-5454

This kit easily record two, four or eight different messages for random-access playback or a single message for 'tape mode' playback.
It also provides cleaner and glitch-free line-level audio output suitable for feeding an amplifier or PA system. It can be powered from any source of 9-14V DC.

- Supplied with silk screened and solder masked PCB and all electronic components
- PCB: 120 x 58mm

Featured in EPE February 2011

£12.75*

Crazy Cricket & Freaky Frog Kit

Cat. KC-5510

A fun first project for a budding electronics enthusiast. Designed to imitate the chirping noise of a cricket or gentle croaking of a frog (alternates at power up), while keeping its location secret to annoy other family members. It activates in darkness and stops when disturbed by light. Kit supplied with PCB, pre-programmed IC, battery and electronic components.

- PCB: 30 x 65mm

NEW

£7.25*

Speedo Corrector Kit for Cars MkII

Cat. KC-5435

£20.00*

When you modify your gearbox, diff ratio or change to a large circumference tyre, it may result in an inaccurate speedometer. This kit alters the speedometer signal up or down from 0% to 99% of the original signal. The input setup selection can be automatically selected and features an LED indicator to show when the input signal is being received. Kit supplied with PCB with overlay and all electronic components.

Best Seller!

- PCB: 105 x 61mm
- Recommended box: UB5 **(use HB-6013 £1.50)**

***All prices EXCLUDE postage & packing**

High Performance 12V Stereo Amplifier Kit

Cat. KC-5495

An ideal project for anyone wanting a compact and portable stereo amp where 12V power is available. No mains voltages, so it's safe as a schoolie's project or as a beginner's first amp. Performance is excellent with 20WRMS per channel at 14.4V into 4 ohms and THD of less than 0.03%. Shortform kit only.

£16.50*

Best Seller!

- 12VDC
- Recommended heatsink **(use HH-8570 £2.25)**
- PCB: 95 x 78mm

Featured in EPE July 2012

Marine Engine Speed Equaliser Kit

Cat. KC-5488

Avoid unnecessary noise and vibration in twin-engine boats. The Engine Speed Equaliser Kit takes the tacho signals from each motor and displays the output on a meter that is centred when both motors are running at the same RPM. When there's a mismatch, the meter shows which motor is running faster and by how much. Simply adjust the throttles to suit. Short form kit only, requires moving coil panel meter **(QP-5010 £6.25)**.

- 12VDC
- Kit supplied with PCB, and all electronic components
- PCB: 105 x 63mm

Featured in EPE November 2011

£14.50*

y

Remote Control Digital Timer Kit

Cat. KC-5496

Remote-controlled digital timer with a bright 20mm-high 7-segment red LED display. It can count up or down from one second to 100 hours in 1-second increments. Its timing period can either be set and controlled using the remote control or it can be automatically controlled via external trigger/reset inputs. An internal relay and buzzer activate when the unit times out. The relay contacts can be used to switch devices rated up to 30VDC or 24VAC and the project can be powered from a plugpack or a battery. Short form kit only - you'll need to add your own universal remote, power supply and enclosure.

£14.50*

- 9-12VDC @300mA
- PCB and components

Featured this Month

PIR Controlled Mains Power Switch Kit

Cat. KC-5455

You've seen those lights fitted with PIR detectors that turn on when someone approaches. Well now you can do the same thing with just about any mains-powered device you like including security systems, decorative lighting, fountain pumps or even commercial advertising etc. The system uses a standard PIR to safely turn on 240VAC mains device(s) for an adjustable pre-set period.

- Kit supplied with case, screen printed PCB, and all electronic components

Featured in EPE April 2011

£29.00*

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ARDUINO Compatible Boards, Modules & Shields

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs (includes Jaycar stepper motors). Arduino projects can be stand-alone, or they can be communicated with software running on your computer. These Arduino development kits are 100% Arduino compatible. Designed in Australia and supported with tutorials, guides, a forum and more at www.freetronics.com. A very active worldwide community and resources are available with many projects, ideas and programs available to freely use.

"Eleven" Arduino-compatible Development Board

Cat. XC-4210

An incredibly versatile programmable board for creating projects. Easily programmed using the free Arduino IDE development environment, and can be connected into your project using a variety of analog and digital inputs and outputs. Accepts expansion shields and can be interfaced with our wide range of sensor, actuator, light, and sound modules.

- 8 analog inputs

£14.50*

LeoStick (Arduino Compatible)

Cat. XC-4266

A tiny Arduino-compatible board that's so small you can plug it straight into your USB port without requiring a cable! Features a full range of analogue and digital I/O, a user-controllable RGB LED on the board and an on-board Piezo/sound generator.

- ATmega32u4 MCU with 2.5k RAM and 32k Flash
- 6 analogue inputs (10-bit ADC) with digital I/O, 14 extra digital I/O pins

£11.00*

EtherMega, Mega sized Arduino 2560 compatible with Ethernet

Cat. XC-4256

The ultimate network-connected Arduino-compatible board: combining an ATmega2560 MCU, onboard Ethernet, a USB-serial converter, a microSD card slot for storing gigabytes of web server content or data, Power-over-Ethernet support, and even an onboard switchmode voltage regulator so it can run on up to 28VDC without overheating.

- 10/100base-T Ethernet built in
- 54 digital I/O lines
- 16 analog inputs
- MicroSD memory card slot
- Prototyping area
- Switchmode power supply

£43.25*

EtherTen, Arduino-compatible with Ethernet

Cat. XC-4216

Includes onboard Ethernet, a USB-serial converter, a microSD card slot for storing gigabytes of web server content or data, and even Power-over-Ethernet support.

- 10/100base-T Ethernet built in
- Used as a web server, remote monitoring and control, home automation projects
- 8 analog inputs

£25.50*

USBDroid, Arduino-compatible with USB-host support

Cat. XC-4222

This special Arduino-compatible board supports the Android Open Accessory Development Kit, which is Google's official platform for designing Android accessories. Plugs straight into your Android device and communicates with it via USB. Includes a built-in phone charger.

- USB host controller chip
- Phone charging circuit built in
- 8 analog inputs
- MicroSD memory card slot

£25.50*

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3-Axis Accelerometer Module

Cat. XC-4226

Easy to use 3-axis accelerometer that provides separate outputs for X, Y, and Z. Very simple to connect to an Arduino or other microcontroller using analog inputs, and easy to read the values into your program or circuit directly.

- Selectable +/-1.5g and +/-6g ranges
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- Built-in 3.3V regulator with 5V-safe I/O lines

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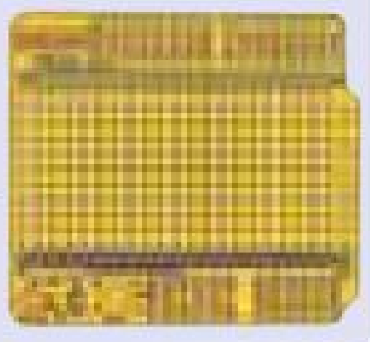
Shift Register Expansion Module	XC-4240	£2.75
Real-Time Clock Module	XC-4272	£11.00

ProtoShield Basic

Cat. XC-4214



A prototyping shield for the Eleven (XC-4210) and USBDroid (XC-4222). Provides plenty of space to add parts to suit any project, keeping everything neat and self-contained. Includes dedicated space to fit a power LED and supply decoupling capacitor.

- Gold-plated surface

£1.75*

Also available:

ProtoShield Short	XC-4248	£2.00
Mega Prototyping Shield	XC-4257	£6.75
LeoStick Prototyping Shield	XC-4268	£3.00
Terminal Shield	XC-4224	£6.25
433MHz Receiver Shield	XC-4220	£11.00
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8 Channel Relay Driver Shield	XC-4276	£12.75

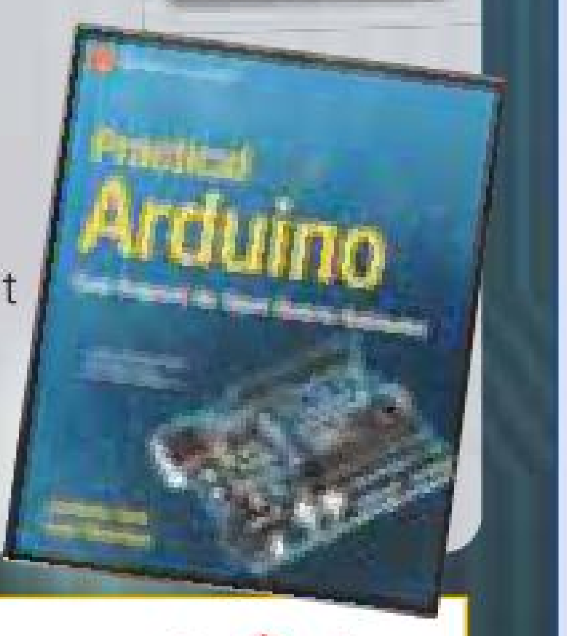
Practical Arduino Book

£18.00*

BM-7132

A large and detailed book that takes you beyond basics quite quickly and shows you how to make up a typical application /design. This is a necessity as it goes to the heart of Arduino.

- Softcover, 422 pages. 235 x 190mm



LCD & Keypad Shield

£11.00*

Cat. XC-4218

Handy 16-character by 2-line display ready to plug straight in to your Arduino, with a software-controllable backlight and 5 buttons for user input. The display is set behind the shield for a low profile appearance and it includes panel mounting screw holes in the corners.

- 2 rows of 16 characters
- Supported by a driver library
- Software-controlled backlight
- Reset button

Large Dot Matrix Display Panel

XC-4250

NOTE: Can for comparison only.

£14.50*

A huge dot matrix LED panel to connect to Eleven (XC-4210), EtherTen (XC-4216) and more! This large, bright 512 LED matrix panel has on-board controller circuitry designed to make it easy to use straight from your board. Clocks, status displays, graphics readouts and all kinds of impressive display projects are ready to create with this display's features.

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Digital Clock Mini Kit
Red 7 Segment display in attractive enclosure, automatic time base selection, battery back-up, 12 or 24Hr modes.
Power: 9Vac or dc
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Heatsink for kit £9.95
VM100 Module £38.54

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Power: 5Vdc 100mA
C-9701 Cebek Module £7.89

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Standard counter, 0 to 99 from input pulses or external signal. With reset input, 13.5mm Displays,
Power: 12Vdc 90mA.
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Compact mono 1.8W RMS 4Ω power stage, short circuit & reverse polarity protection. 30-18kHz, Power: 4-14Vdc 150mA
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Mono amplifier with 2 channels (Low & High frequecy), 20W RMS 4Ω per channel, adjustable high level. 22-22kHz, short circuit & reverse polarity protection.
Power: 8-18Vdc 2A
E-14 Cebek Module £22.11

5W Stereo Amplifier
Stereo power stage with 5W RMS 4Ω, 30-18kHz, short circuit & reverse polarity protection.
Power: 6-15Vdc 500mA
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Single rail regulated power supply complete with transformer. 130mA max, low ripple, 12Vdc with adjustment.
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Power: 12Vdc 80mA
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Power: 12Vdc 60mA
I-4 Cebek Module £13.98

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Power: 12Vdc 60mA
I-6 Cebek Module £13.08

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VOL. 41 No. 8 AUGUST 2012

How well protected is your domestic supply?

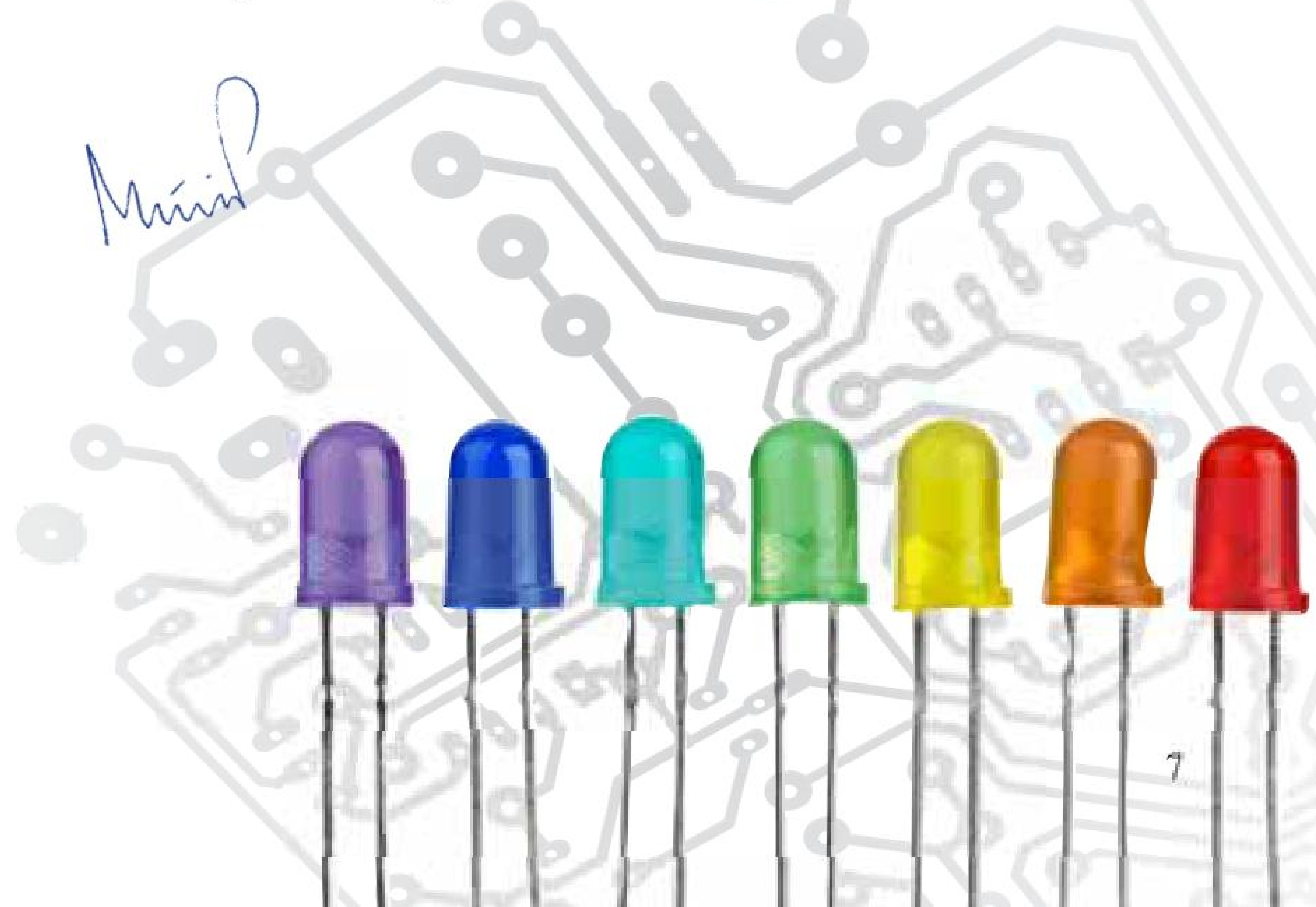
This month's editorial is a brief update on last month's piece, which was devoted to the worrying story of how one loose wire and a 'normal' domestic current can cause a fire. Reading it reminded me that fires are not the only hazard that a correctly rated and installed fuse or over-current trip can fail to protect against.

It is very easy to receive a nasty, even fatal electric shock from just a few dozen milliamps – exactly how much depends on many variables, including the victim's health and the duration of the shock. The point here is that such a low current will hardly register on a 13A fuse, let alone the main house fuses, which are often rated up to 45A or more.

Fortunately, there is a device, which in many (but not all) circumstances will protect against shock; it's the 'residual-current device', commonly shortened to RCD. Many of you will be familiar with this useful piece of safety equipment, so I will only give a brief overview of its operation. The key to the RCD's operation is the clever use of a current transformer to detect if there is a difference between the current flowing in the live and neutral conductors. If there is a difference above a certain level, typically 30mA for 30ms, then the circuit is tripped. The reason for highlighting the current difference is that if the currents are not the same then there must be a 'leakage current', in other words, the current potentially flowing into you.

I bring up RCDs in the context of my close encounter with electrical trouble not because it would have protected against a fire – it wouldn't – but because it is another example of why it's worth having your domestic supply checked. As I explained last month, my house electric distribution is fairly antiquated and was clearly built up over several decades. The only protection I had was old-fashioned wire fuses. While these are legal and do work to protect against dangerous over-currents, modern regulations now require all new installations to include RCD protection for all sockets. They are undoubtedly an important safety device; so, if like me, you think it's time to have your house wiring checked, then don't forget to consider replacing your old fuseboard with something much more up to date, which includes not just over-current protection, but also RCD protection.

Don't take your domestic wiring or protection systems for granted – get them checked professionally.



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NEWS

A roundup of the latest Everyday News from the world of electronics

Panasonic go for 3D gold at London 2012 by Barry Fox

Panasonic is delivering the largest supply of audio-visual equipment for any Olympic Games' says Sean Taylor, senior manager at Panasonic's London Olympic project office in London. 'Beijing was the first HD Olympic Games. Vancouver was the first Full HD Games. London will be the first 3D Games, with over 200 hours of 3D cover – shot with solid-state 3D cameras.'

'Panasonic is providing all the AV equipment for the 2012 Games; 300 P2HD/DVCPRO HD recorders, 100 P2HD camera recorders, 30 3D cameras, 1000 monitors, 2500 CCTV cameras, 12,000 consumer TVs for athletes (with their picture settings locked), and 22 DLP projectors'

'We have been working with LOCOG, the London Organising Committee of the Olympic and Paralympic Games, at seven test events where we used 760 different scenarios to try and break the system.'

Panasonic
HD
FUJINON

Panasonic are supplying hundreds of their latest HD and 3D cameras to cover London 2012

New projector

A completely new projector design, beaming 20,000 lumens, will be installed for the Opening – and Closing – Ceremonies. These PTDZ21K WUXGA (1920 × 1200) projectors use 3-Chip DLP technology, consume 2300 watts and have a geometric adjustment function that allows projected images to be shaped and 'wrapped' to tailored screens and complex surfaces. How they will be used remains a secret, except for the bare bones title 'Isles of Wonder', inspired by Shakespeare's *The Tempest*.

Video signals from twin-lens 3D camera recorders (AG-3DP1) will be distributed by the International Broadcasting Centre (IBC) to the broadcasters of each country in HD format. File-based AVC-Intra standards will be used alongside conventional DVCPRO HD video.

Game on

The 400m^2 'Panasonic Full HD 3D Theatre', in the Olympic Park, at Stratford, will be open throughout the Games, from 28 July to 12 August. Inside, a Full HD 3D Theatre will use a 152-inch PDP (plasma display panel) and 103-inch PDP to screen live 3D. The press centre will house two 145-inch PDPs.

With 26 Olympic sports and 20 Paralympic sports, in 36 competition venues across the UK, the 2012 Games equate to staging 46 World Championships simultaneously with 14,700 athletes, 21,000 media and broadcasters and approximately 10.8 million ticket-holders. The Olympic Park is the size of 357 soccer pitches. HD video conferencing will link the venues to LOCOG HQ in London.

For the public, there will be 45 LED screens at 28 venues, with screen area totalling 1730m^2. Each screen is built from tiles of 16 LEDs. In addition, forty-seven 103-inch PDPs will be suspended in 28 venues, one in the middle of a waterway. Most of the screens will be left for legacy use.

Panasonic will also provide two 145-inch 8k (7680 × 4320) Super Hi Vision PDPs (one working, one spare) in the Media Centre. These will screen footage shot by the BBC and NHK. The screens scan vertically rather than horizontally to stabilise image quality.

Although Panasonic sees the 2012 Games as a landmark for 3D, viewers may not see them that way. When the BBC announced its Olympic broadcast plans in early April, all the emphasis was on providing satellite and cable operators with 24 channels of free-to-air cover, in Hi Def and on a non-exclusive basis, for the duration of the Games.

3D caution

The BBC's only commitment to 3D is to 'include' the Opening Ceremony, Closing Ceremony, Men's 100m final and a highlights package at the end of each day.

For the thinking behind the BBC's low-key 3D cover you have to dig into the BBC's website, where Roger Mosey, director, BBC London 2012, has written:

'We've always been clear we were never going to have a 3D channel for the Olympics and the BBC's overall approach to 3D has been very much on the lines of an experiment around special events like *Wimbledon* and *Strictly Come Dancing*.

'This caution has been in line with consumer demand – 3D has spread more slowly than we perhaps expected in 2009, and there have been interesting developments abroad with France's Canal Plus announcing that it's stopping its 3D channel because it just hadn't met its targets.

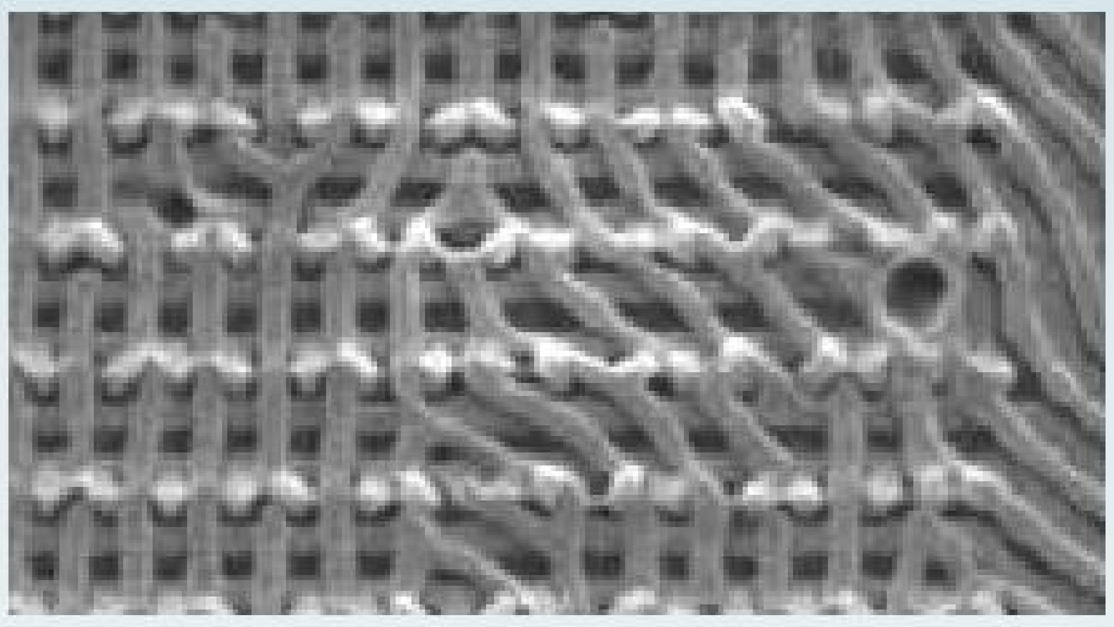
'The pattern will be that our main standard-definition transmission will be on BBC One, the HD simulcast will be on BBC One HD and then the 3D version will be on the BBC HD Channel – as we did with Wimbledon.'

The BBC's low-key approach has spurred Sky into working separately with Eurosport to transmit over a hundred hours of 3D cover. But this will only be available by satellite.

Sean Taylor says Panasonic is 'working with dealers and looking at ways of bringing 3D to a wider audience'.

Nanoscale building

Researchers at MIT have found a new way of making complex three-dimensional structures using self-assembling polymer materials that form tiny wires and junctions. The work could usher in a new generation of microchips Although similar structures with very fine wires have been produced before, this is the first time the structures have been extended into three dimensions with different, independent configurations on different layers.



The 3D nanoscale structures are much finer than those from conventional lithography

Pico launches budget four-channel, USB-powered oscilloscopes

PicoScope's 3000 Series of high-performance oscilloscopes has been expanded to include six new four-channel models. The new oscilloscopes offer a maximum sampling rate of 1GS/s (up to 10GS/s effective for repetitive signals), a range of input bandwidths from 60MHz to 200MHz, and buffer memory depths from 4M to 128M samples. The new FlexiPower system allows the scopes to run on either USB or AC power. With an option of either a built-in function generator or a built-in arbitrary waveform generator, and a new, slim case design, these scopes are perfect for hobbyists, engineers and technicians needing a complete, portable test bench in a single unit.

The PicoScope oscilloscope software includes as standard all the oscilloscope and spectrum analyser functions you would expect, as well as serial decoding, mask limit testing, segmented memory and advanced triggers: features that often cost extra on other manufacturers' scopes. Running on your Windows PC, PicoScope shows waveforms on a large, clear display and allows easy zooming and panning under keyboard or mouse control.

Other built-in features include persistence displays with fast waveform update rates, maths channels, automatic measurements with statistics, programmable alarms, and decoding of I2C, UART/RS232, SPI, CAN bus, LIN and FlexRay signals. Updates to the software are released regularly, free of charge.

Pico's new 3000 series of keenly priced USB-powered four-channel oscilloscopes

A free Software Development Kit (SDK) allows you to control the new scopes from your own custom applications. The SDK includes example programs in C, C++, Excel and LabVIEW, and can be used with any language that supports C calling conventions. The PicoScope software and SDK are compatible with Microsoft Windows XP, Windows Vista and Windows 7.

Prices start at £599 for the 60MHz PicoScope 3404A with function generator to only £1349 for the 200MHz PicoScope 3406B with AWG, including four probes and a five-year warranty. For more details, see: **www.picotech.com**

Featured Engineer

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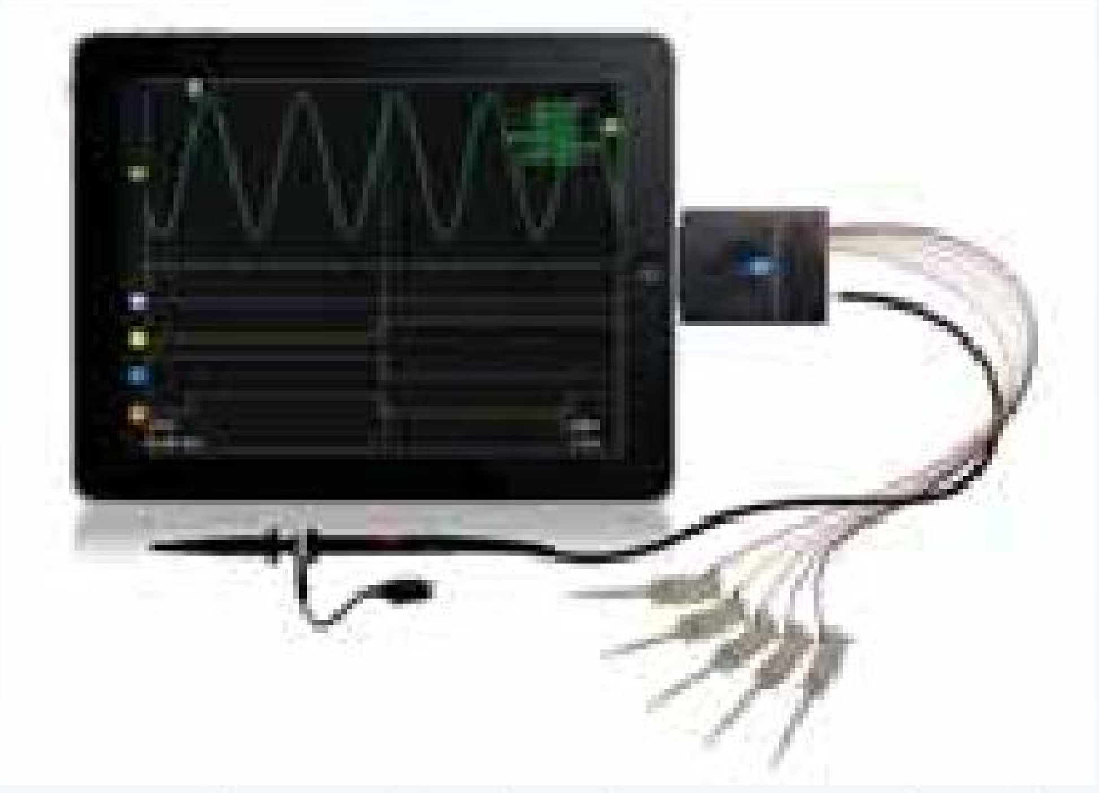
Featured Engineer

Alan Winstanley

Well done Alan!

Following on from his triumph with 'Engineering Site of the Day' (see last month's News) EPE's *Alan Winstanley has been interviewed as EEWeb's Featured Engineer. It makes for interesting reading and is a well-deserved accolade, see:* ***www.eeweb.com/spotlight/interview-with-alan-winstanley***



Not just for Facebook and music – Audon Electronics iMSO-104's adapter for iOS devices

Audon Electronics is now offering the iMSO-104, a mixed-signal oscilloscope that moves Apple's iOS devices and touch-screen interface into the test and measurement world. Priced at £199+VAT, the iMSO-104 is a 5MHz oscilloscope adapter for iPod touch, iPhone and iPad that is intuitive and easy to use, for more details, please see: **www.audon.co.uk/handscopes/imso104.html**

STM32 mikroElektronika launch

MikroElektronika has announced the release of an entire toolchain for STM32 microcontrollers. New versions of mikroC, mikroBasic and mikroPascal compilers for ARM now include 186 new microcontrollers from STM32, including Cortex-M3 and Cortex-M4. mikroElektronika has introduced over 50 libraries and dozens of examples that will get designers and hobbysits started in no time. Further details are available at: ***www.mikroe.com/eng/categories/view/116/stm32-solution***

Ultrasonic Cleaner

By JOHN CLARKE

You may know that you can obtain compact ultrasonic cleaners for jewellery and similar small items. So why not a much larger version? It would be great for cleaning automotive and other mechanical parts, fabrics which cannot be machine washed, ornate bric-a-brac and a host of other hard-to-clean items.

ANYONE who has ever needed to clean the parts for a carburettor, differential, gearbox or any other greasy and intricate parts must have often wished for an easier way.

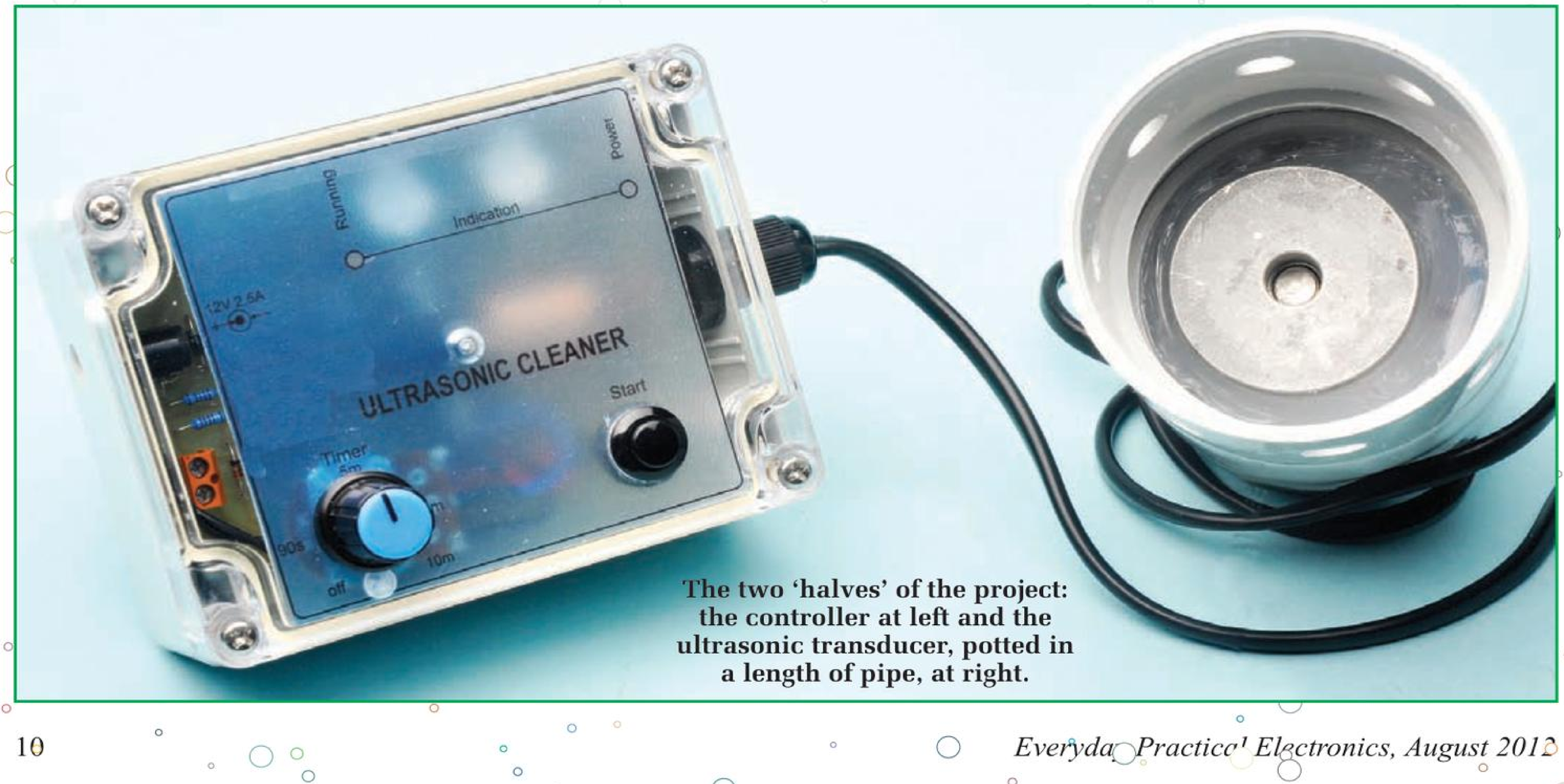
Generally, you dunk the parts in a container of kerosene, dieseline detergent or whatever; soak it for a while and then return to the task with various brushes and implements to scrape off the grease and other gunk. It is a dirty and tedious task.

But what if you could dispense with all that brushing and scraping? If you could just drop the components in a tank of suitable solvent, press a button and then come back later to remove the parts in sparkling clean condition?

Our ultrasonic cleaner is designed to do exactly that job. It uses a high power piezoelectric transducer and an ultrasonic driver to literally blast away the dirt and grime with ultrasonic energy.

The solvent might be kerosene or hot water and a wetting agent such as detergent. At low drive levels the solvent conducts the ultrasonic signal throughout the bath. At higher power levels, the ultrasonic wavefront causes cavitation, which causes bubbles to form and then collapse. This is shown in Fig.1.

As the wavefront passes, normal pressure is restored and the bubble collapses to produce a shock wave. This



The two ‘halves’ of the project: the controller at left and the ultrasonic transducer, potted in a length of pipe, at right.

Cleaning a coffee-stained stainless steel tray in our 'bath' (actually an old plastic cistern – see page 17). You can't see the bubbles being generated in this photo – they're too small – but they are certainly there.

Features

- 12V plugpack powered
- Automatic timeout
- Adjustable timeout
- Start button
- Rugged transducer

WARNING!

This circuit produces an output voltage of up to 800V peak-peak to drive the ultrasonic transducer and is capable of delivering a severe (*or even FATAL*) electric shock. DO NOT touch the output terminals at CON3, the PC tracks leading to CON3 or the transducer terminals when power is applied.

To ensure safety, the PC board must be housed in the recommended plastic case, while the transducer must be correctly housed and fully encapsulated in resin, as described in the article.

shock wave helps to loosen particles from the item being cleaned.

The size of the bubbles is dependent upon the ultrasonic frequency and is smaller with higher frequencies.

Industrial ultrasonic cleaners tend to use frequencies between 20kHz and 50kHz, while cleaners for small parts typically use frequencies above 50kHz.

Our ultrasonic cleaner sweeps the frequency range from about 19kHz to 42kHz to produce cavitation bubbles of varying sizes. The frequency is varied with an irregular pattern to avoid a constant low frequency sub-harmonic in the cleaning bath or tank. Variation of the sub-harmonic frequency reduces the impact of resonances in small items being cleaned that may otherwise cause them to disintegrate.

This variation in frequency also prevents standing waves in the cleaning bath that can produce cavitation in one area but no cavitation in another area. This can lead to irregular cleaning action of a component.

Actual power delivered is dependent upon the resonant frequency of the piezo transducer. For this *Ultrasonic Cleaner*, maximum power delivered by the transducer is at about 40kHz, which is the resonant frequency of the specified piezo ultrasonic transducer.

The *Ultrasonic Cleaner* can be set to run for between 30 seconds and 10 minutes.

Alternative sweep pattern

An alternative sweep pattern is available that sweeps over a frequency range of around 12kHz, centred on the 40kHz resonance. This produces a higher agitation level in the cleaning bath due to the transducer frequently running through its resonance. This alternative sweep pattern should be for intermittent use only. Which sweep pattern is best depends on the component being cleaned and the type of contamination.

The driver for our cleaner is housed in a small plastic case. This connects to the piezoelectric ultrasonic transducer using a length of sheathed two-core mains-rated cable. The piezoelectric

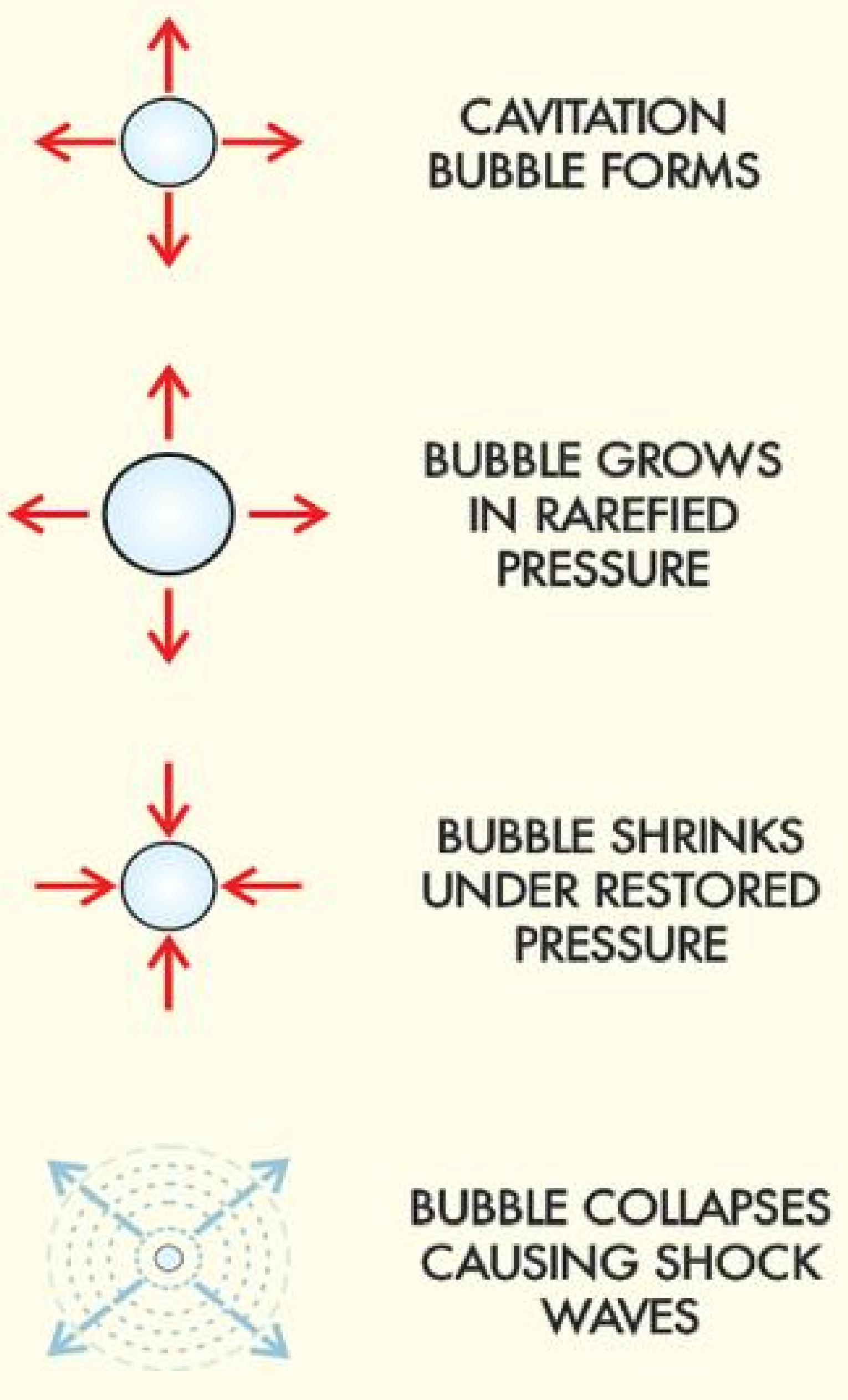
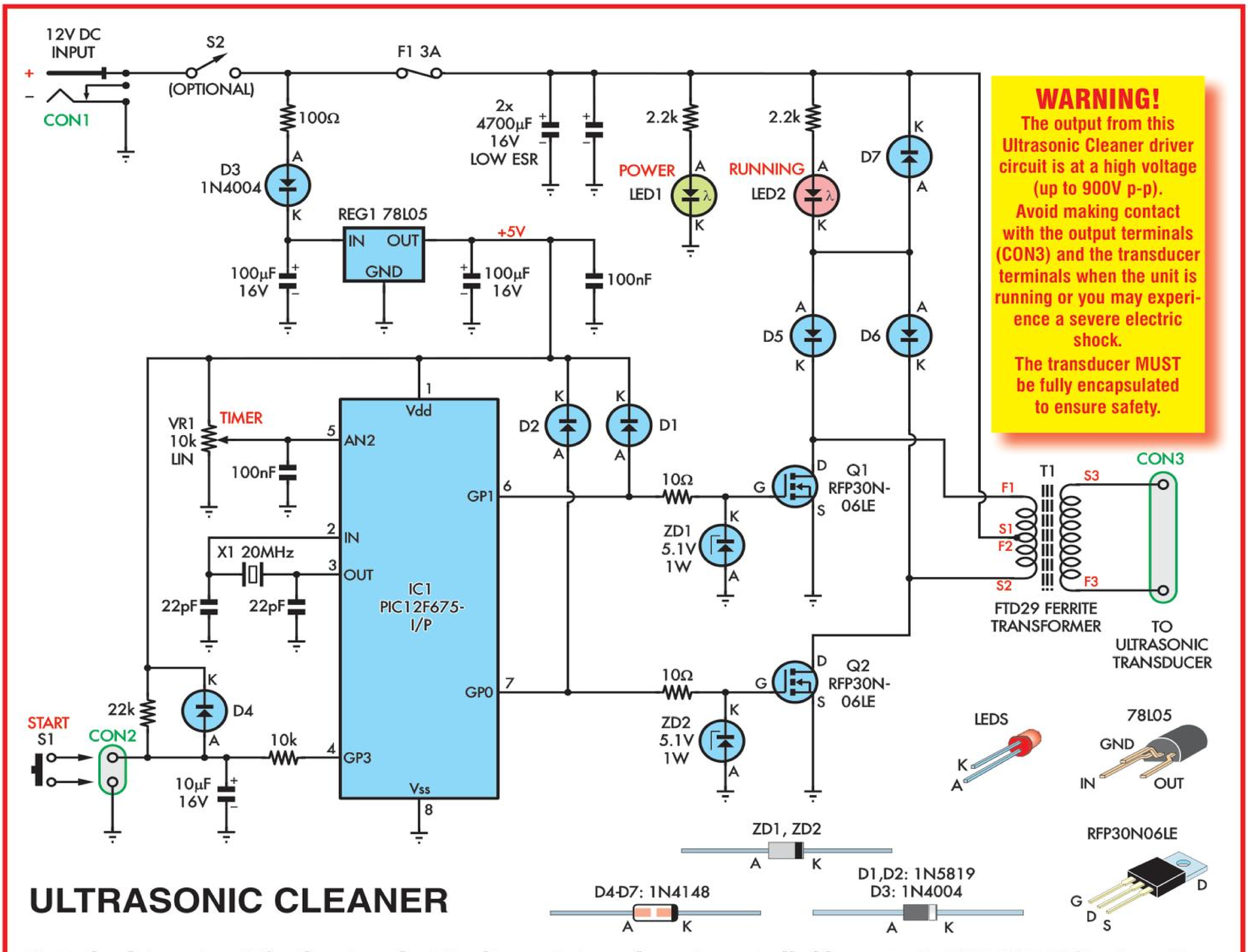

CAVITATION BUBBLE FORMS
BUBBLE GROWS IN RAREFIED PRESSURE
BUBBLE SHRINKS UNDER RESTORED PRESSURE
BUBBLE COLLAPSES CAUSING SHOCK WAVES
NEW CAVITATION BUBBLE FORMS

Fig.1: the ultrasonic cleaning process. It's all about causing shock waves in the cleaning solvent to literally 'shake off' the dirt and grime. You *can* do this manually – but the ultrasonic transducer does it 40,000 times each second!


12V DC INPUT
+
–
CON1
S2 (OPTIONAL)
F1 3A
100Ω
D3 1N4004
A
K
REG1 78L05
IN
OUT
GND
+5V
100µF 16V
100µF 16V
100nF
2x 4700µF 16V LOW ESR
2.2k
2.2k
POWER
LED1
RUNNING
LED2
D7
D5
D6
VR1 10k LIN
TIMER
100nF
X1 20MHz
22pF
22pF
IC1 PIC12F675-I/P
Vdd
AN2
IN
OUT
GP1
GP0
GP3
Vss
1
5
2
3
6
7
4
8
D2
D1
10Ω
10Ω
ZD1 5.1V 1W
ZD2 5.1V 1W
Q1 RFP30N-06LE
Q2 RFP30N-06LE
G
D
S
T1
F1
S1
F2
S2
S3
F3
FTD29 FERRITE TRANSFORMER
CON3
TO ULTRASONIC TRANSDUCER
START S1
CON2
22k
D4
10k
10µF 16V
LEDS
78L05
GND
IN
OUT
ZD1, ZD2
D4-D7: 1N4148
D1,D2: 1N5819
D3: 1N4004
RFP30N06LE
ULTRASONIC CLEANER

WARNING!
The output from this Ultrasonic Cleaner driver circuit is at a high voltage (up to 900V p-p). Avoid making contact with the output terminals (CON3) and the transducer terminals when the unit is running or you may experience a severe electric shock.
The transducer MUST be fully encapsulated to ensure safety.

Fig.2: the driver circuit for the piezoelectric ultrasonic transducer is controlled by an 8-pin PIC12F675-I/P micro. Two oscillation modes are available, the alternative is selected by holding the 'start' button down as power is applied.

transducer is housed in a PVC fitting that covers and insulates the terminals from accidental contact. This is *essential*, because the transducer is driven at a high voltage, which could cause a nasty shock if you come into contact with it.

The piezo transducer and housing can be directly immersed in the ultrasonic bath or tank. Alternatively, the transducer can be glued to the outside of the bath using epoxy resin for deeper baths.

Circuit details

The full circuit diagram of our *Ultrasonic Cleaner* is shown in Fig.2. It is relatively simple due to the use of an 8-pin PIC12F675-I/P programmed microcontroller, IC1. This drives the piezoelectric transducer via two MOSFETs (Q1 and Q2) and transformer (T1). The microcontroller also provides the timer and start functions.

Crystal X1 sets the microcontroller to run at 20MHz. This frequency allows the ultrasonic drive to be shifted in small increments amounting to 320Hz at around 40kHz.

Outputs GP0 and GP1 provide complementary gate-drive signals for MOSFETs Q1 and Q2. Since these outputs only swing from 0V to 5V, Q1 and Q2 are logic-level MOSFETs. Standard MOSFETs require gate signals of at least 10V for full conduction, but logic-level MOSFETs will fully conduct with much less.

For the RFP30N06LE MOSFETs specified, the on-resistance between drain (D) and source (S) is a mere 75mΩ at 20A, at a gate voltage of 3V. The on resistance drops further to around 23mΩ at 20A at the higher gate voltage of 4.5V. The MOSFETs are rated at 30A continuous.

Q1 and Q2 are driven alternately, and these in turn drive

Specifications

Power requirements	12V at 2.5A
Transducer voltage	250V AC square wave
Frequency range	Main mode is 19kHz to 42kHz with irregular variation
Alternative frequency range	34kHz to 44kHz
Timeout adjustment	30s to 10m

the separate halves of the transformer primary, which has its centre tap connected to the +12V supply. When MOSFET Q1 is switched on, current flows in its section of the transformer primary winding.

Q1 remains on for less than 50µs, depending on the frequency, and is then switched off. Both MOSFETs are then off for a few microseconds before Q2 is switched on. It is then switched on for the same duration as for Q1, and then both MOSFETs remain off for a few microseconds before Q1 is switched on again. The gap when both MOSFETs are off is the 'dead time', and it allows each MOSFET to fully switch off before the other is switched on.

The alternate switching action of the MOSFETs generates an AC square wave in the secondary, and since the primary/secondary turns ratio is 11.25:1, the secondary winding delivers about 250V AC to the piezoelectric transducer from 19kHz to 42kHz.

Some protection

MOSFETs Q1 and Q2 include over-voltage protection, which clamps any drain voltage that exceeds 60V. This clamping is required, because a high-voltage transient occurs when the transformer primary winding is switched off.

Protection for the gate of each MOSFET is provided by using 5.1V Zener diodes. Although the MOSFET gate is only driven from a 5V signal, the high transient voltage at the drain can be coupled into the gate via capacitance between gate and drain. The 5.1V Zener diodes prevent a higher voltage driving IC1's GP0 and GP1 inputs, which could damage them.

Further protection is provided for GP0 and GP1 using diodes D1 and D2, which are in parallel with the chip's internal protection diodes. These clamp and carry the current if the voltage at these pins goes above about 5.3V.

Running indication

LED2 indicates when the MOSFETs are switching on and off. When Q1 is switched on, diode D5 can power LED2 via the 2.2kΩ resistor from the 12V supply. When Q2 is switched on, the LED is driven via D6. When both Q1 and Q2 are off, the LED is not driven.

When either Q1 or Q2 are switched off, the high voltage from the transformer primary winding at the MOSFETs' drain can couple through diodes D5 or D6 due to capacitance. Diode D7 clamps the voltage to 0.7V above the 12V supply to protect LED2.

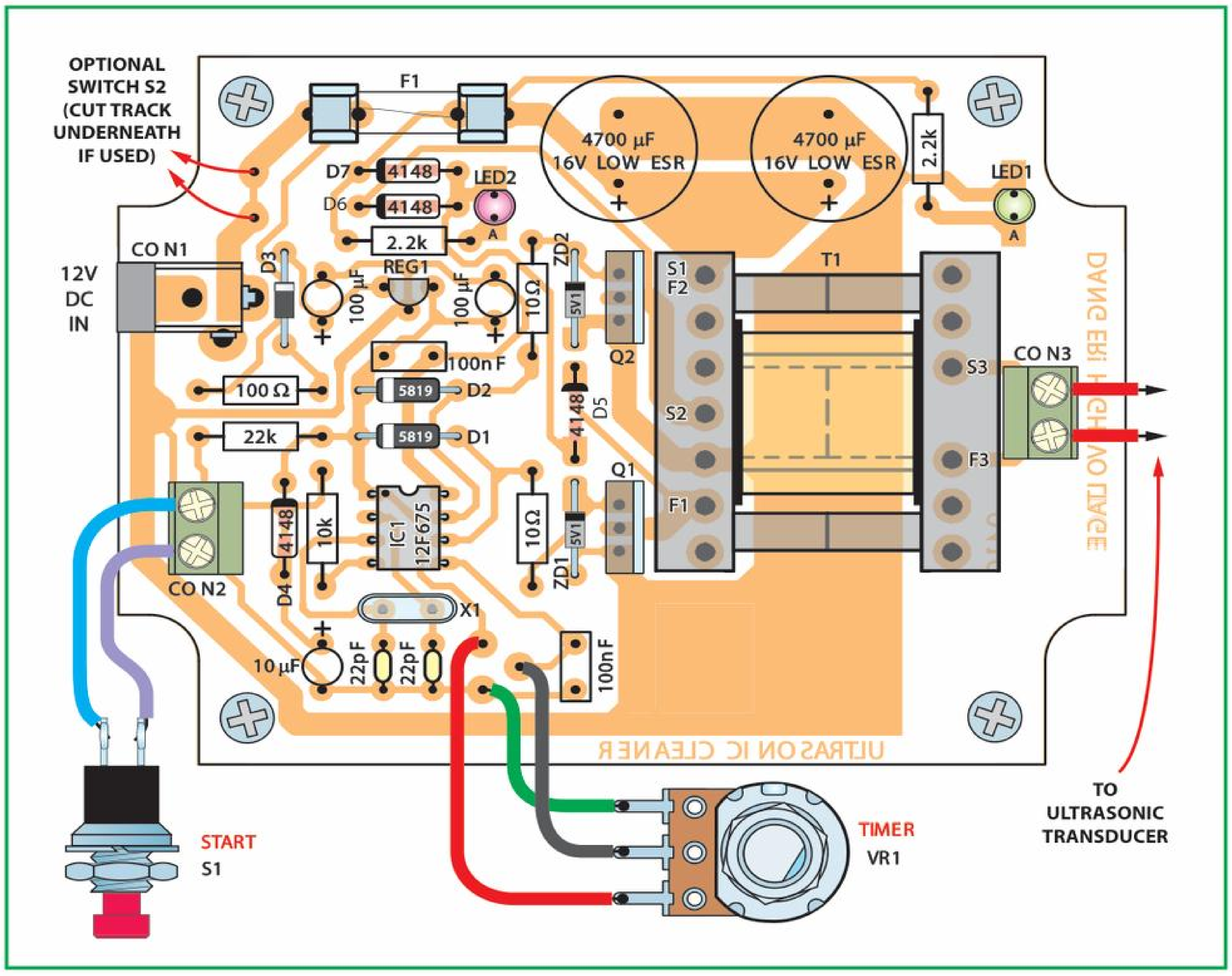
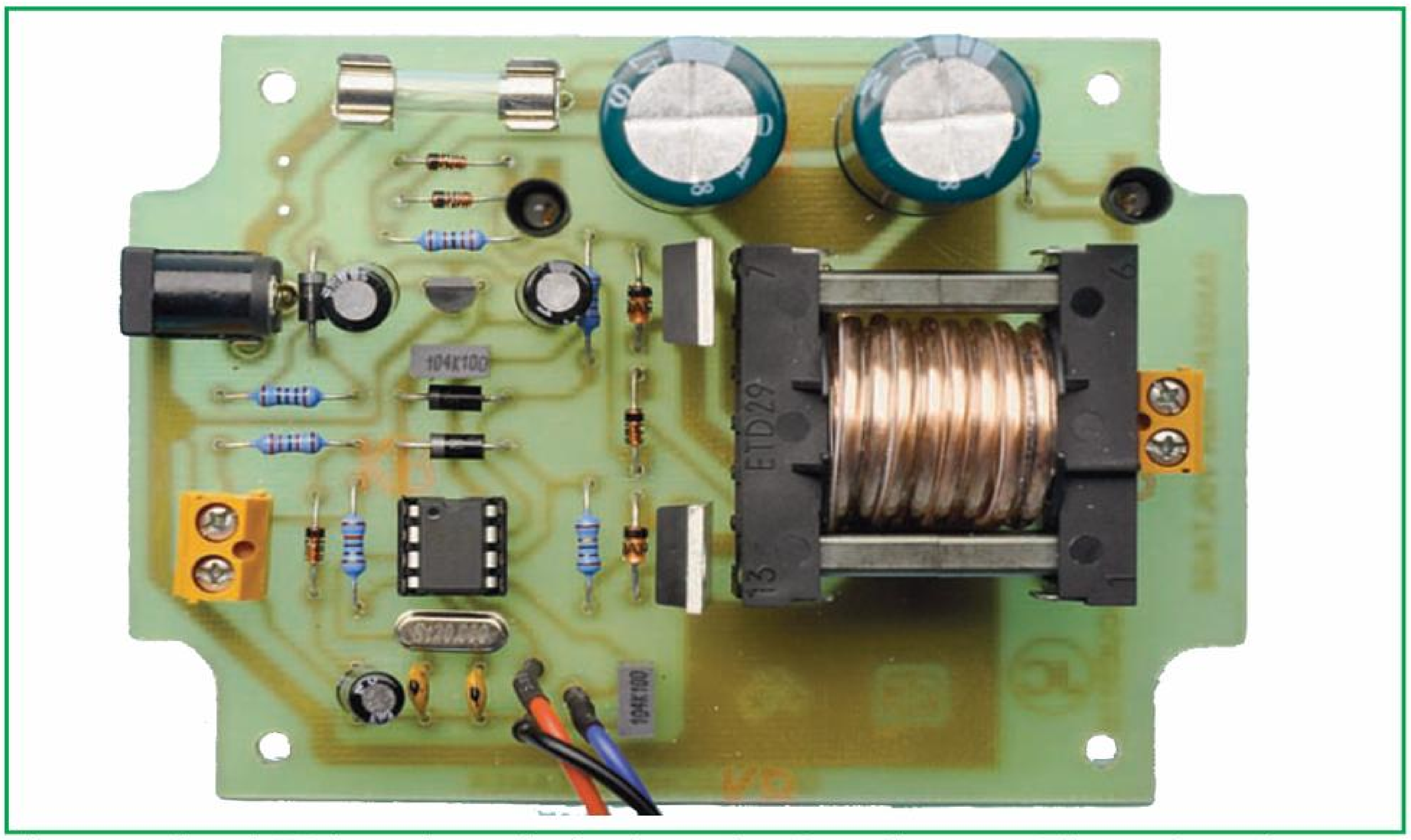

OPTIONAL SWITCH S2 (CUT TRACK UNDERNEATH IF USED)
F1
4700 µF 16V LOW ESR
4700 µF 16V LOW ESR
2.2k
LED1
A
D7 4148
D6 4148
LED2
A
2.2k
ZD2
CON1
12V DC IN
D3
100 µF
REG1
100 µF
10Ω
5V1
Q2
S1
F2
T1
DANGER! HIGH VOLTAGE
100nF
100 Ω
5819 D2
4148 D5
S2
S3
CON3
22k
5819 D1
Q1
F1
F3
4148
10k
IC1 12F675
10Ω
5V1
ZD1
CON2
D4
X1
10 µF
22pF
22pF
100nF
ULTRASONIC CLEANER
START S1
TIMER VR1
TO ULTRASONIC TRANSDUCER

Fig.3: component overlay for the Ultrasonic Cleaner. All components (except the start button, timer pot and transducer) are mounted on a single-sided PC board. If an on/off switch is required, the copper track must be cut between the S2 pins.

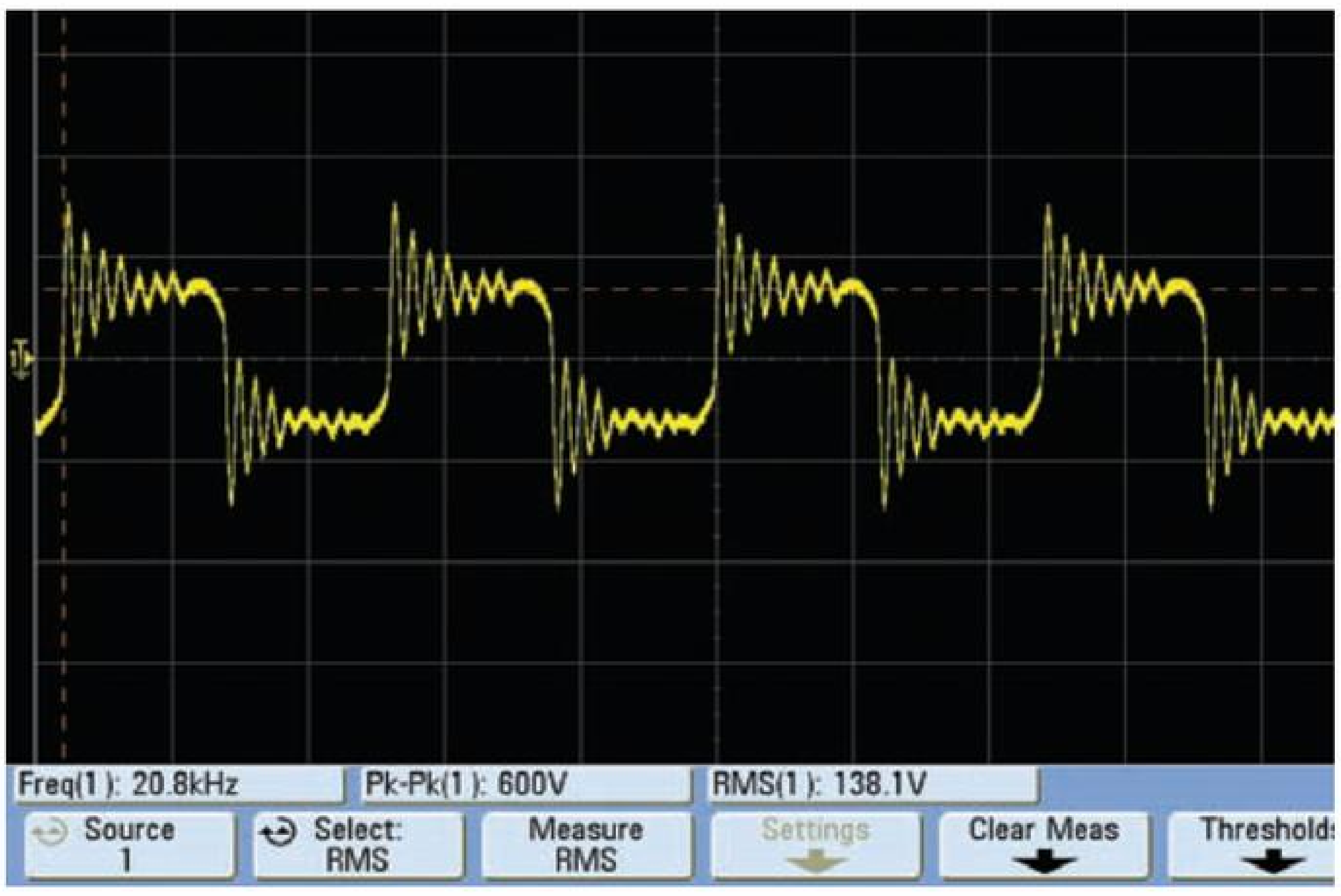
Timer

IC1 also performs the timer function. This switches off all drive to the MOSFETs after a preset time period, set by the position of potentiometer VR1. VR1 is wired across the 5V supply with the voltage at the wiper monitored by IC1 at the AN2 (pin 5) input. IC1 converts the voltage into a digital value, which is used as a basis for the timeout.

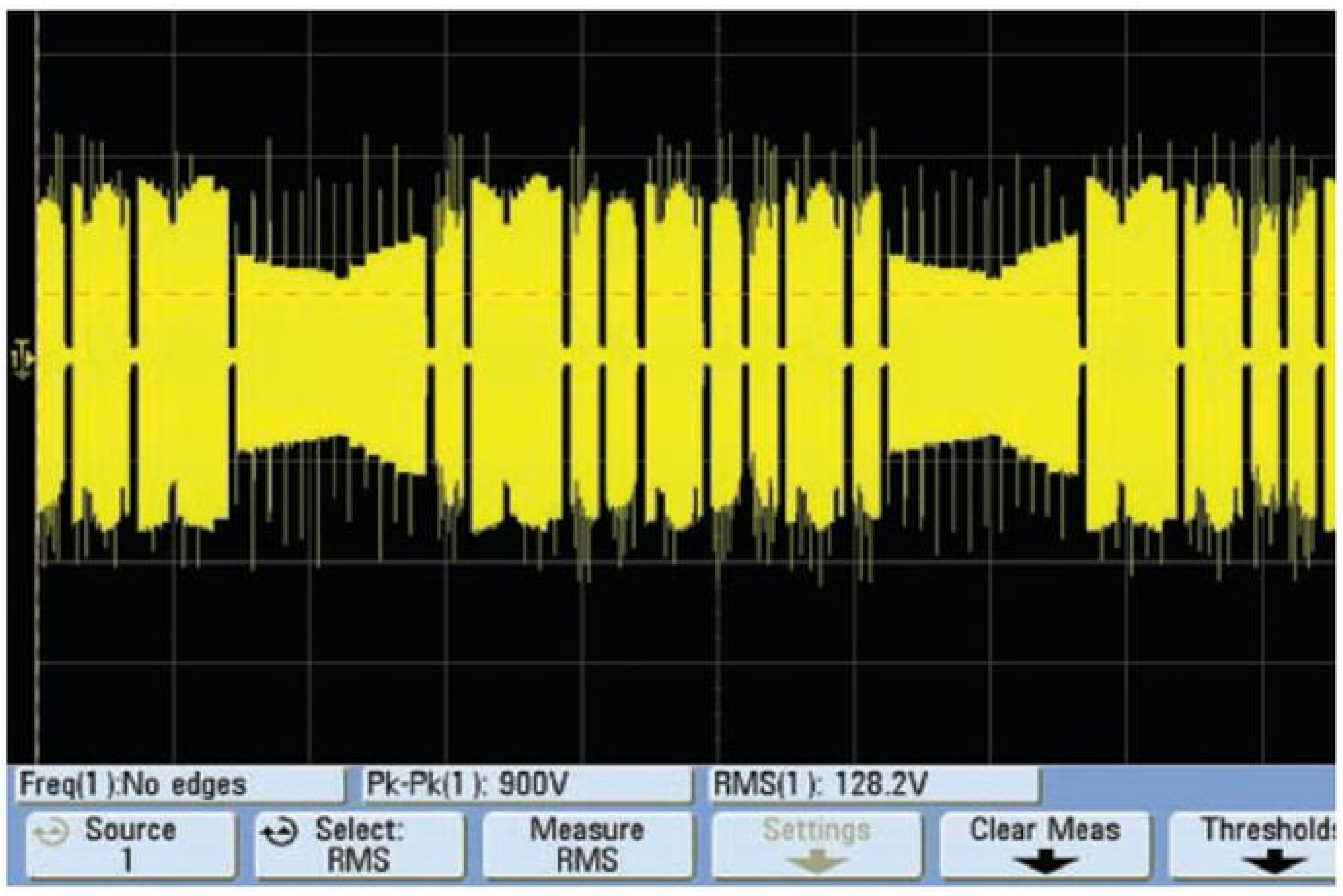
The maximum timeout of 10 minutes is set with the wiper of VR1 at



The completed PC board, ready for insertion into the case. The on-board power switch (S2) is not used here – the two PC pin holes (top left) are empty and the thin copper track underneath is intact.


Freq(1): 20.8kHz | Pk-Pk(1): 600V | RMS(1): 138.1V
Source
1
Select:
RMS
Measure
RMS
Settings
Clear Meas
Thresholds

The voltage waveform appearing at the ultrasonic transducer as it is swept over a range of frequencies. In this case, it is shown at 20.8kHz. Note the high peak-peak voltage of 600V.


Freq(1):No edges | Pk-Pk(1): 900V | RMS(1): 128.2V
Source
1
Select:
RMS
Measure
RMS
Settings
Clear Meas
Thresholds

Taken at a low sweep speed, this waveform shows the transducer driven with bursts of different frequencies. In this case the maximum peak-to-peak voltage is 900V – danger!

5V, with shorter timeouts as VR1 is reduced. The lowest practical setting is about 30s. When the potentiometer is set to its minimum position, the timer will not run and the MOSFETs are kept off. If the potentiometer is rotated to this minimum position during the running of the timer, the timer will also be switched off, turning off the MOSFETs.

Starting the ultrasonic drive is initiated by pressing the start switch. Normally, the GP3 input (pin 4) is held at 5V via a 22kΩ pull-up resistor. When the switch is pressed, this input is pulled to 0V and signals IC1 to run the ultrasonic drive.

When S1 is released, the 10µF capacitor across the switch charges up to 5V via the 22kΩ resistor. Diode D4 discharges the capacitor when power is switched off, and the 5V supply rail drops to 0V.

Power supply

The 5V power for IC1 is derived from the 12V supply via a 100Ω resistor, reverse polarity protection diode D3 and 5V regulator, REG1. The supply to REG1 is filtered with a 100µF capacitor, while the 5V output is bypassed using 100nF and 100µF capacitors.

Reverse polarity protection for the power section of the circuit is via a 3A fuse (F1), along with the integral reverse diode within each MOSFET. These diodes conduct current through the primary windings of transformer T1, effectively clamping the supply voltage at –0.7V, protecting the 4700µF electrolytic capacitors from excessive reverse voltage.

The 12V 2.5A plugpack includes foldback current limiting where current at voltage below 12V is reduced from its maximum rating of 2.5A. With a short circuit, the current limit is around 0.5A. The fuse is unlikely to blow and power dissipation in the MOSFETs is around 0.35W total. This does not cause any harm to the MOSFETs, the transformer or the capacitors.

The fuse is included to prevent the PC board tracks from fusing should the transformer be wound incorrectly or if one of the MOSFETs fails as a short circuit.

Power-on indication is via LED1, run via a 2.2kΩ resistor from the 12V supply.

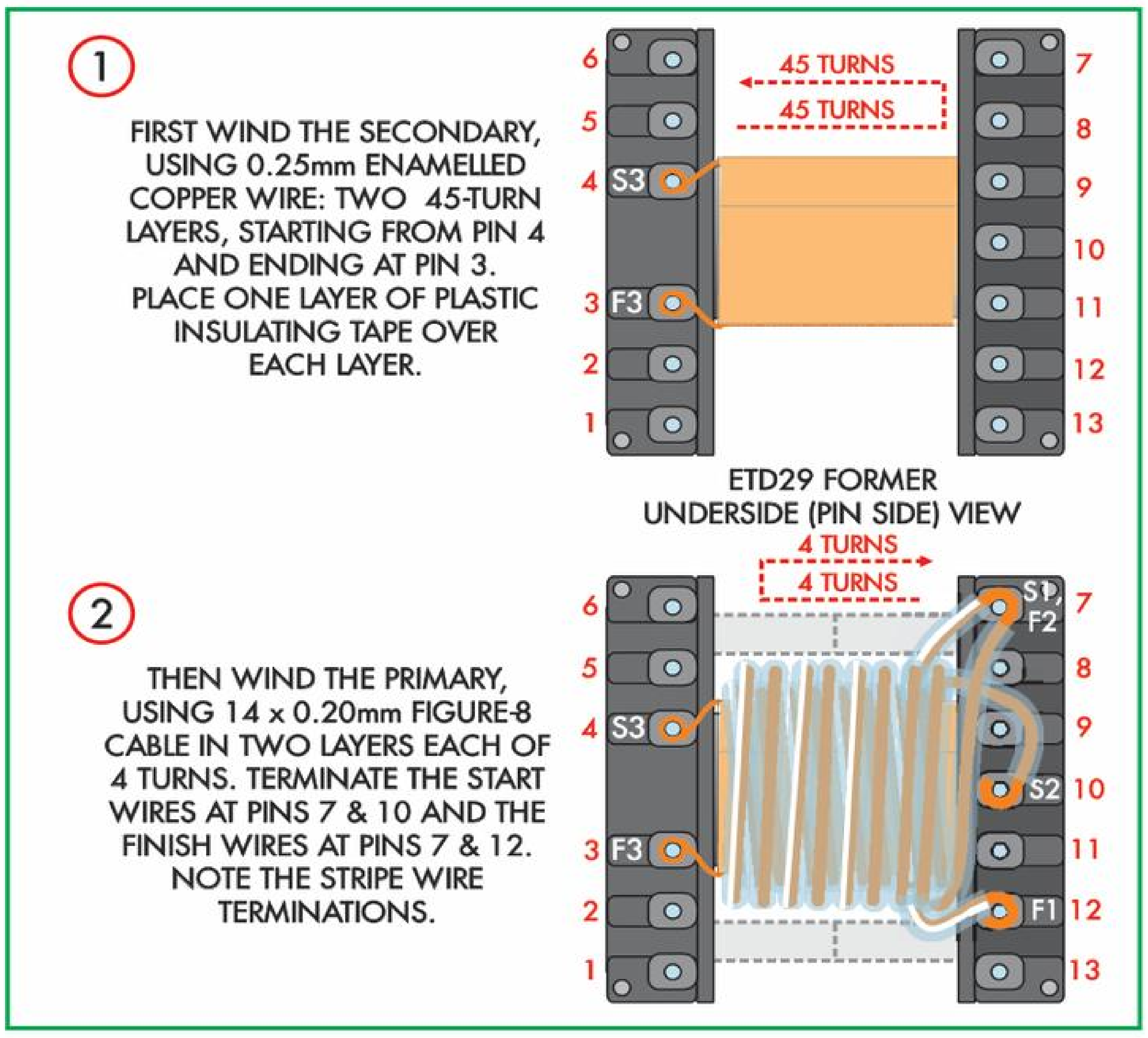

①
FIRST WIND THE SECONDARY, USING 0.25mm ENAMELLED COPPER WIRE: TWO 45-TURN LAYERS, STARTING FROM PIN 4 AND ENDING AT PIN 3. PLACE ONE LAYER OF PLASTIC INSULATING TAPE OVER EACH LAYER.
45 TURNS
45 TURNS
S3
F3
6
5
4
3
2
1
7
8
9
10
11
12
13
ETD29 FORMER UNDERSIDE (PIN SIDE) VIEW
②
THEN WIND THE PRIMARY, USING 14 x 0.20mm FIGURE-8 CABLE IN TWO LAYERS EACH OF 4 TURNS. TERMINATE THE START WIRES AT PINS 7 & 10 AND THE FINISH WIRES AT PINS 7 & 12. NOTE THE STRIPE WIRE TERMINATIONS.
4 TURNS
4 TURNS
S1
F2
S2
F1
S3
F3
6
5
4
3
2
1
7
8
9
10
11
12
13

Fig.4: winding details for the on-board transformer, T1. The secondaries are conventional enamelled copper wire, while the primaries are wound with figure-8 wire.

Construction

The *Ultrasonic Cleaner* is constructed on a PC board, coded 862, and measures 104mm × 78mm. This board is available from the *EPE PCB Service*. The circuit board is mounted in an IP65 ABS box with a clear lid, measuring 115mm × 90mm × 55mm. The clear lid allows the power and running LEDs to be seen without having to drill extra holes.

The PC board is designed to mount onto the mounting bushes inside the specified box. Make sure the PC board is shaped to the correct outline so it fits into the box. It can be filed to shape if necessary using the PC board outline as a guide.

Begin construction by checking the PC board for breaks in tracks or shorts between tracks and pads. Repair if necessary. Check the hole sizes are correct for each component to fit neatly. The screw terminal holes and transformer pin holes are 1.25mm in diameter compared to the 0.9mm holes for the

ICs, resistors and diodes. Larger holes are used for the DC socket and fuse clips.

Normally, power can be switched on and off by switching the plugpack at the power point. However, if you prefer to have a separate switch for the *Ultrasonic Cleaner*, we have provided the option to include a power on and off switch (S2) that is wired between two PC stakes on the PC board.

If you are not using the switch then the PC stakes do not need to be installed. If you are using a switch, then the PC stakes are installed and the thinned track between the PC stakes is broken using a hobby knife. However, PC stakes are required to be installed for the three connection points for rotary potentiometer VR1.

Assembly can begin by inserting the resistors. Use a digital multimeter (DMM) to measure and check each value. The diodes can now be installed, with the orientation shown. Note that there are four different diode types: 1N5819s for D1 and D2, 1N4004 for D3 and 1N4148s for D4 to D7. The fourth type is a 1N4733 5.1V 1W Zener. It's probably safest to install D4 to D7 first, being all the same type.

IC1 is mounted on a DIP8 socket, with the notch positioned as shown. **Install the socket now, but leave IC1 out for the time being.**

The crystal (X1), the DC socket and the two 2-way screw terminals can be installed next, with the screw terminals oriented with the opening toward the outside edge of the PC board. MOSFETs Q1 and Q2 are mounted so that their metal tabs face the transformer and are about 25mm above the PC board. REG1 can also be mounted now. None of these components require heatsinks.

The LEDs are mounted with the top of each LED 30mm above the PC board. Again, take care with orientation: the anode has the longer lead. Capacitors can be mounted next, ensuring the electrolytic types are oriented correctly. The two main supply electrolytics (4700µF 16V) *must* be low ESR types.

Parts List – Ultrasonic Cleaner

1 PC board, code 862, available from the *EPE PCB Service*, size 104mm × 78mm
1 IP65 ABS box with clear lid, 115mm × 90mm × 55mm (Jaycar HB6246 or equivalent)
1 12V 2.5A plugpack
1 50W ultrasonic transducer with 40kHz resonance (Jaycar AU5556 or equivalent)
1 65mm PVC DWV (drain, waste and vent) end cap
1 65mm PVC pipe 40mm long to suit end cap
1 ETD29 ferrite transformer (RS Components 231-8656) with 2 × 3C85 cores, a 13-pin former and 2 retaining clips (T1)
1 2.5mm PC mount DC socket (CON1)
1 SPST momentary closed panel switch (S1)
1 SPDT toggle switch (S2 - optional)
1 3A M205 fuse (F1)
2 M205 fuse clips
2 2-way screw terminals (CON2, CON3)
1 DIP8 IC socket for IC1
1 knob to suit VR1
2 cable glands for 6mm cable
1 20MHz crystal (X1)
3 PC stakes (VR1 board terminals)
2 PC stakes (optional for S2)
2 solder lugs (ultrasonic transducer terminals)
2 M4 × 10mm screws (ultrasonic transducer solder lugs)
2 M4 nuts (ultrasonic transducer solder lugs)
2 4mm star washers (ultrasonic transducer solder lugs)
4 M3 × 6mm screws (PC board to case)
1m twin-core mains flex (ultrasonic transducer lead)
1 300mm length of 14 × 0.20mm or 14 × 0.18mm fig-8 wire (prim, T1)
1 3m length of 0.25mm enamelled copper wire (secondary T1)
1 300mm length of black hookup wire (S1 and VR1)
1 50mm of red hookup wire (VR1)
1 50mm of blue hookup wire (VR1)
1 100mm length of yellow hookup wire (optional for S2)
1 240mm length of 2mm heatshrink tubing (VR1 and PC stakes and S1 terminals)
1 40mm length of 5mm heatshrink tubing (ultrasonic transducer terminals)
1 40mm length of 5mm black heatshrink tubing (LED1,LED2 covering)

Semiconductors

1 PIC12F675-I/P programmed microcontroller (IC1)
1 78L05 5V regulator (REG1)
2 RFP30N06LE 30A 60V Logic level MOSFETs (Q1,Q2)
2 1N4733 5.1V 1W Zener diodes (ZD1,ZD2)
1 1N4004 1A diode (D3)
4 1N4148 switching diodes (D4 to D7)
2 1N5819 1A Schottky diodes (D1,D2)
2 3mm LEDs (LED1,LED2)

Capacitors

2 4700µF 16V low ESR
2 100µF 16V radial elect.
1 10µF 16V radial elect.
2 100nF MKT polyester
2 22pF ceramic

Resistors (0.25W 1%)

1 22kΩ
1 10kΩ
2 2.2kΩ
1 100Ω
2 10Ω
1 10kΩ linear pot with knob (VR1)

Miscellaneous

Neutral cure silicone sealant suitable for wet areas (eg, roof and gutter sealant)
Epoxy resin (eg, J-B Weld)

Software

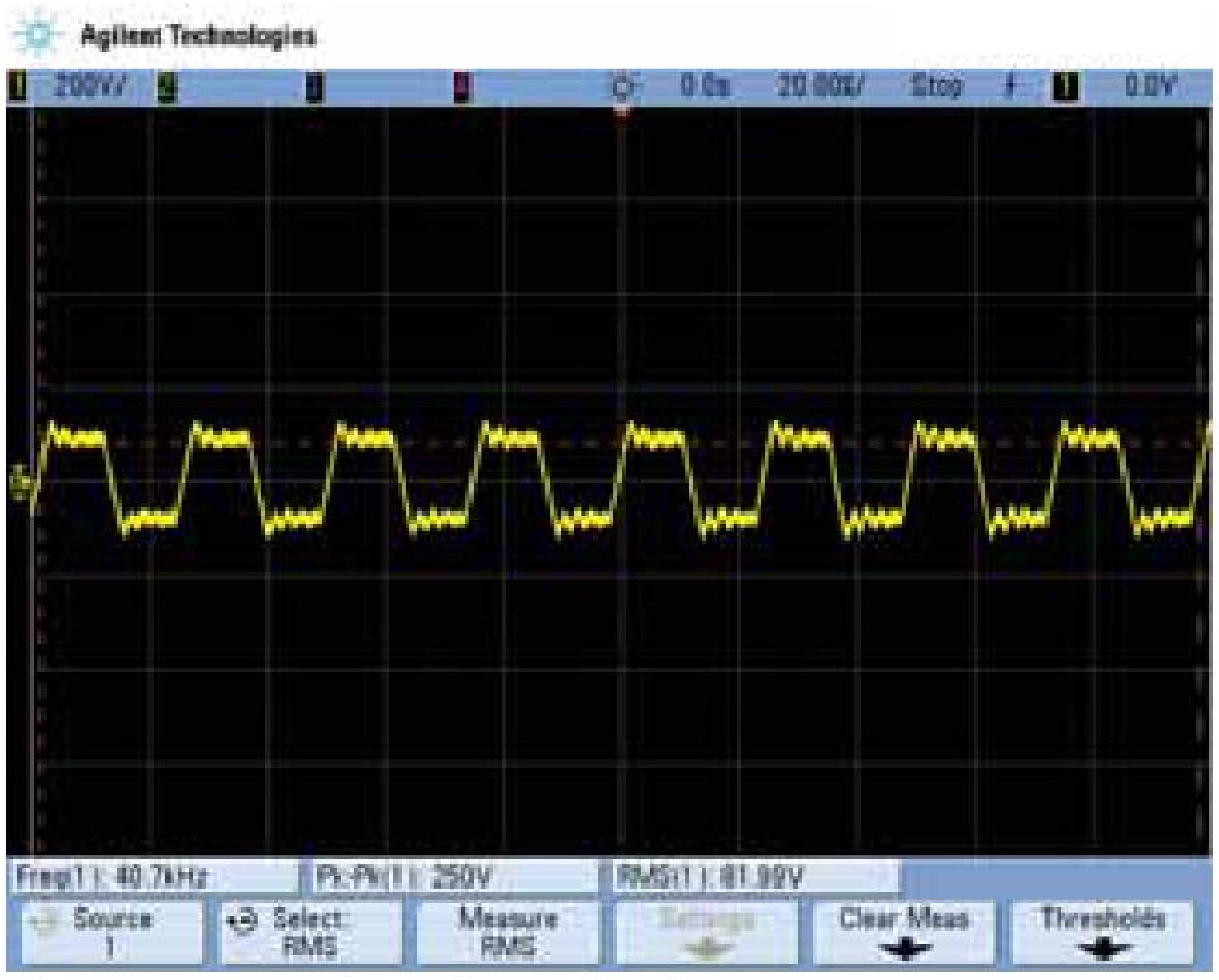
All software program files will be available from the *EPE* website at **www.epemag.com**.

Although we do not supply pre-programmed microcontrollers, you can purchase the programmed micro featured in this project from: **parts@siliconchip.com.au**

Winding the transformer

The ferrite transformer winding details are shown in Fig.4. The primary winding uses standard polarity-marked figure-8 wire, either 14mm × 0.20mm or 14mm × 0.18mm, wound in two layers. The secondary uses 0.25mm enamelled copper wire wound in two layers with a layer of insulation tape between the first and second layers.

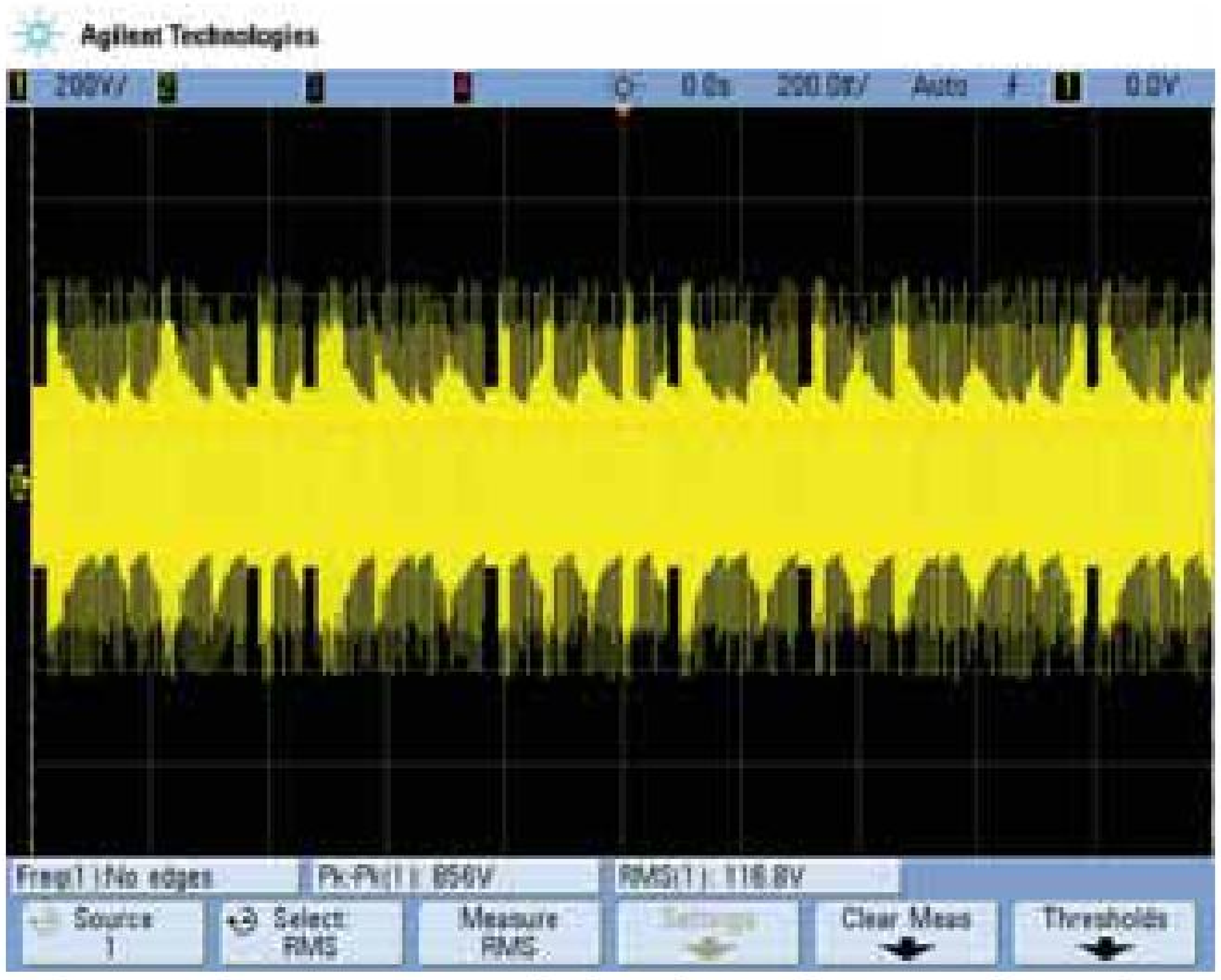
Start by winding the secondary winding. First, remove the enamel from one end of the 0.25mm enamelled copper wire (use some fine emery paper or a hobby knife to scrape it off). Pre-tin (solder) the wire end and wrap it around pin 4 on the underside of the transformer bobbin and solder close to the bobbin. Now close-wind 45 turns (ie, side-by-side) until the windings reach the opposite end of the former. The direction of winding does not matter. Cover the windings in a layer of insulation tape.



200V/ 0.0s 20.00$/ Stop 0.0V

Freq(1): 40.7kHz Pk-Pk(1): 250V RMS(1): 81.99V

This scope waveform shows the cleaner in continuous mode, where it is swept over a small range of frequencies centred around 40kHz.



200V/ 0.0s 200.0$/ Auto 0.0V

Freq(1):No edges Pk-Pk(1): 856V RMS(1): 116.8V

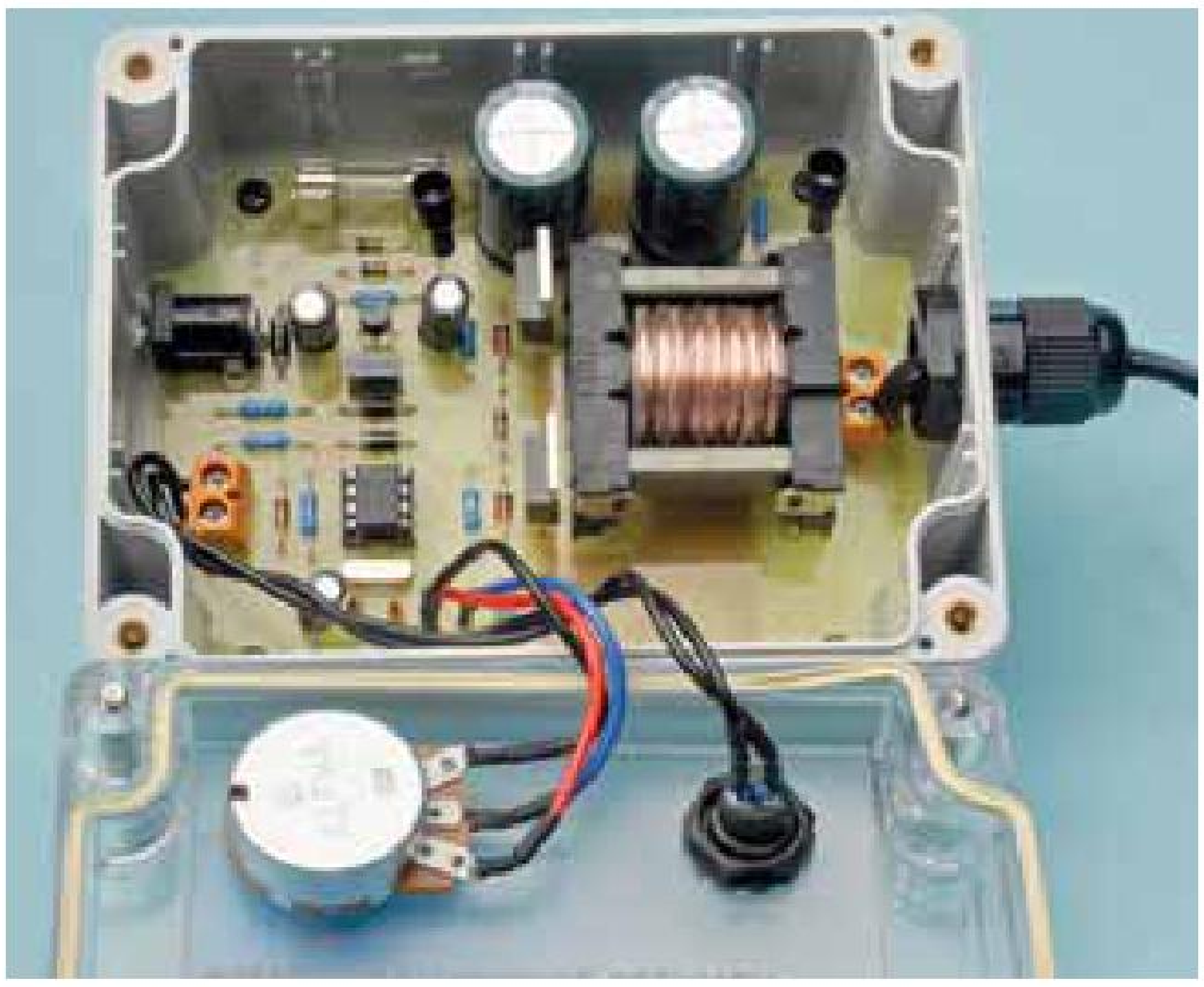
Taken at a low sweep speed, this shows that transducer drive is continuous rather than being pulsed at different frequencies.

Continue winding back over the first layer, in the same direction as before (ie, clockwise or anticlockwise) to complete 90 turns. Terminate the wire on to terminal pin 3 in the same way as was done for terminal 4.

The primary winding, made from the figure-8 cable, is first stripped of insulation at about 10mm from the ends and the two wires are soldered close to the bobbin at terminal pin 7 and pin 10. Place the wire with the polarity stripe to pin 7. Now wind on four turns, making sure the wire lies flat without twisting so the striped wire stays to the left.

The four turns should fully fill the bobbin, and the next four turns will be on the next layer (there's no need for insulation tape between them). Terminate the striped wire end onto pin 12 and the other wire to pin 7.

Once wound, slide the cores into the former and secure with the clips. These clips push on to the core ends and clip into lugs on the side of the bobbin. The transformer can be installed into the PC board holes and soldered in place. Install it on the PC board, noting that the primary side has seven pins and the secondary side has six pins.



Here's how it goes together in the case. Only the timer pot (VR1) and the start switch (S1) are mounted on the lid of the case, which is translucent to allow the LEDs to shine through.

That completes the assembly of the PC board.

Case preperation

Cut the potentiometer shaft so that it is 12mm long or to suit the knob used. A suggested front-panel (84mm × 80mm) and rough guide to the positioning of the start switch (S1) and rotary potentiometer (VR1) that mount on the case lid is shown in the early photographs. The wiring from these two components to the circuit board can be seen in the photo below left.

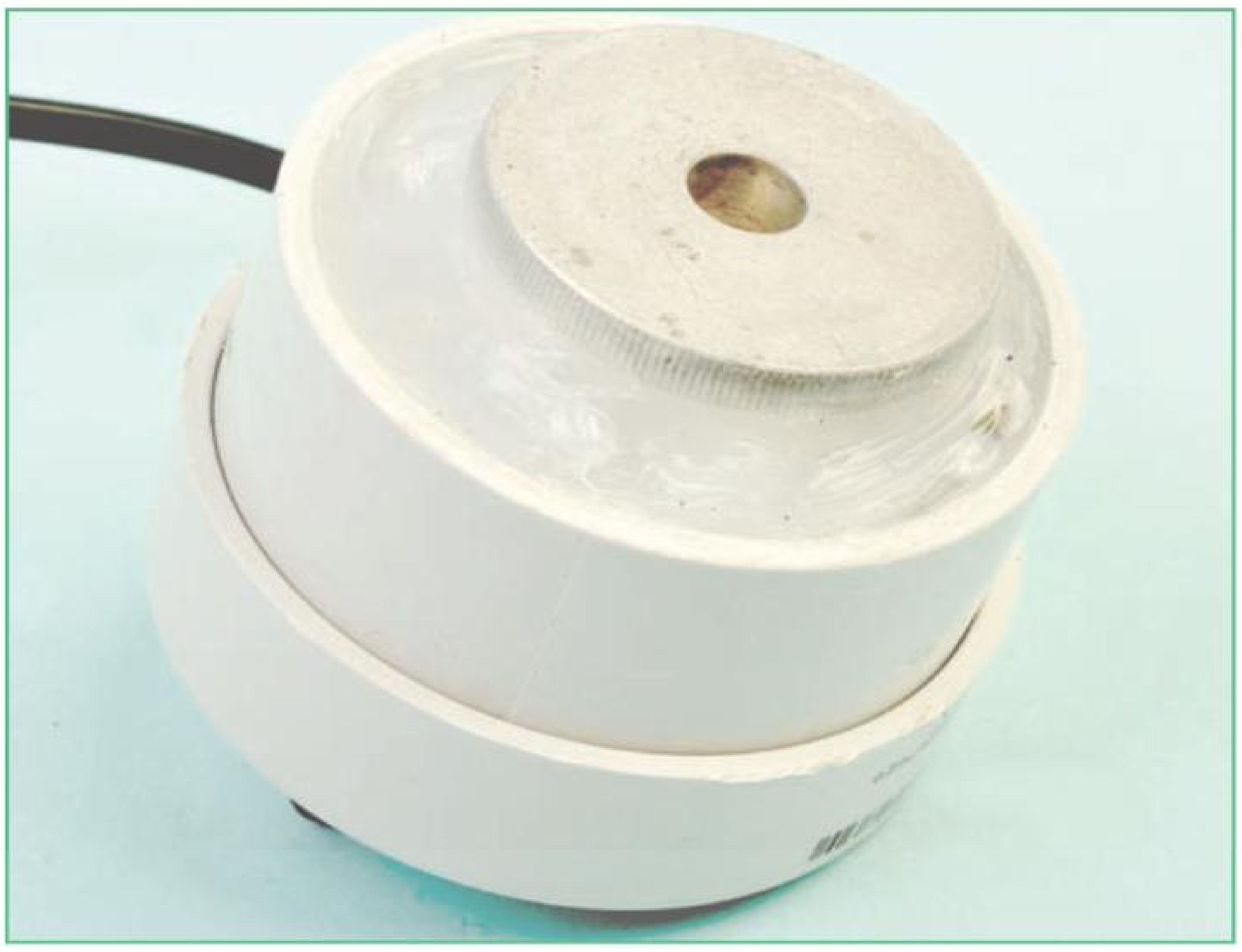
The label is mounted inside the lid to protect it. Cut the holes out for the switch and potentiometer using a hobby knife, then attach it to the lid using clear tape, spray adhesive or clear silicone sealant.

The switch and potentiometer are wired as shown (Fig.3) using hookup wire and heatshrink tubing over the soldered terminations. The heatshrink tubing helps prevent the wires from breaking off the terminals. Note that the switch is best attached to the lid before connecting the wires to the PC board. The potentiometer can be wired while it is off the lid and attached after wiring.

So that light only shines through the lid where the power and running indications are located on the front panel label, the two LEDs are fitted with short 'light tubes'.

We used approximately 20mm lengths of 5mm tubing and temporarily inserted the DC power plug from the 12V plugpack into one end of the tubing to about 4mm inside the tube end. This acted as a heatshrink tubing former. Then the other end of the heatshrink tube was placed over the LED and the tubing was shrunk down using a heat gun. The DC plug was removed after the tubing had cooled, leaving a round tube shape above the LED. Without the DC plug inserted first, the tube would shrink up too tightly.

Holes are required in the ends of the box for the power connector and for the cable gland for the lead to the ultrasonic transducer. The power connector hole is 8mm in



The transducer 'potted' into some PVC plumbing fittings with silicone sealant, ready for attachment to a suitable cleaning tank. Make sure the terminals are covered!

diameter and is located 31mm to the right of the outside left box edge and 16mm up from the outside base of the box.

The 12mm cable gland hole is located on the opposite end of the box, 27mm up from the base edge and in the centre.

Supply check

The 12V 2.5A plugpack is supplied with several connectors. Choose the one that fits the DC socket, then attach this connector to the DC plugpack lead with the + marking on the connector plug to the + marking on the connector socket. With the plug removed from the DC socket, check that there is 12V at the connector plug and that the centre hole is the + terminal and the outside is the – terminal.

Now check that IC1 is OUT of its socket and remove fuse F1 (this step is important for safety reasons and to ensure F1 doesn't blow with IC1 out of circuit). That done, plug the DC connector into the DC socket and check that there is 5V between pins 1 and 8 of IC1's socket (pin 1 should be at +5V with respect to pin 8). In practice, this voltage could be between 4.85V and 5.15V, but will typically be close to 5V.

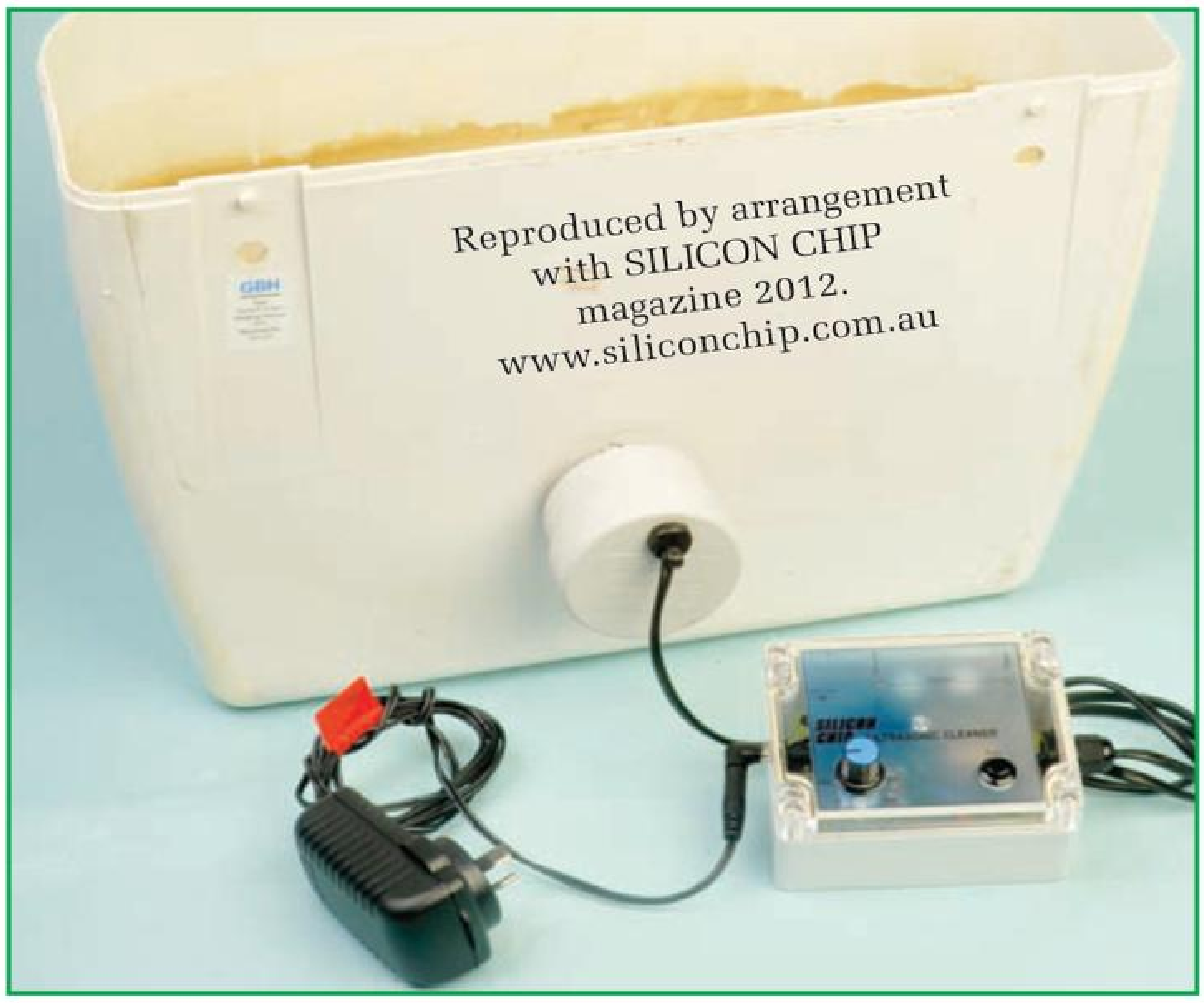
If the voltage is correct, switch off and place the board to one side. **DO NOT install IC1 or the fuse – that comes later.**

Piezoelectric transducer

Note that the voltage at CON3, and thus across the terminals of the piezoelectric transducer, can be up to 900V peak-to-peak or so (see scope waveforms) – you MUST avoid contact with these terminals when the driver is running. THIS VOLTAGE IS POTENTIALLY LETHAL!

Use 2-core sheathed mains cord for wiring to the ultrasonic transducer. The wire terminates onto solder lugs and is covered with heatshrink tubing. The terminals are secured to the ultrasonic transducer terminals using an M4 screw, star washer and M4 nut for each. These terminals on the transducer are exposed and need to be protected within a housing to prevent contact.

A suitable housing is made up using 65mm PVC DWV (drain, waste and vent) fittings. As mentioned, the ultrasonic transducer can be directly inserted into a bath if the transducer is raised sufficiently so that the lower 5mm of the transducer is immersed in the fluid. A typical housing is shown in the photo on page 10.



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Keeping the plumbing theme going(!), here's our cleaning tank: an old cistern, with holes suitably plugged, with the smooth face of the transducer glued directly to the outside of the case using J-B Weld. You could use just about any metal or plastic leakproof container as a tank. Ours works a treat!

Alternatively, the transducer can be secured to the outside of a 'bath' using epoxy resin, as shown above. We used an end cap and a 40mm length of pipe to house the transducer.

The wire entry is via a cord grip grommet that secures to the end cap so that the wires cannot be pulled out to leave exposed live wires. Shape the cord grip grommet hole so that it is captured correctly within the end cap and holds the wire securely. The twin-core sheathed cable we used was not held securely with the cord grip grommet and so we looped the cable in an 'S' shape so that three layers of the wire are captured in the grommet.

The transducer should be mounted within the enclosure using neutral cure silicone sealant (such as roof and gutter sealant). The lower section of the transducer should be kept free from the sealant. This is so that the transducer can more effectively couple to the liquid in the bath, either directly, or when secured to the outside of the bath with epoxy resin. Make sure the electrical terminals are covered with silicone to provide insulation and prevent accidental contact.

Connecting the ultrasonic driver cable to the PC board is best done before the board is mounted in the box. Ensure the power is off and pass the 2-core sheathed mains cord through the cable gland locking nut, the cable gland itself (which means it goes through the box) and carefully connect the two wires to the output terminals (CON3). Make absolutely sure there are no strands of copper wire emerging from the terminals which could short them out.

The *Ultrasonic Cleaner* PC board can now be installed in the box and secured using the four M3 × 6mm screws. That done, pull the 2-core mains cable through the cable gland so it has a just little slack inside the box and secure the cable with the locking nut on the gland.

Why is ultrasonic cleaning effective?

A component that has contaminants on its outside layer can be cleaned by physical removal of the contaminants or by dissolving the contaminant. Which process works depends upon the contaminant.

For example, solids are more effectively removed by physical means, whereas oils are better removed by dissolving in a solution. Sometimes a combination of physical dislodging and chemical dissolving of contaminants is necessary to remove various combinations of contaminants.

Ultrasonic energy improves both the dissolving and physical removal of the contaminant. Where ultrasonics is used as an aid in the dissolving process can be seen in Fig.5 to Fig.7. Fig.5 shows a component that has a contaminant adhered to its surface that is placed in a cleaning fluid solution.

As the cleaning fluid begins to dissolve the contaminant, it becomes saturated with the contaminant and so it loses its effectiveness in cleaning (Fig.6).

However, as shown in Fig.7, when ultrasonic excitation is included in the cleaning process, the saturated cleaning fluid is displaced, allowing fresh cleaning fluid to come into contact with the contaminant to dissolve it. As shown, the component surface is a flat edge that could be cleaned with a mechanical method other than ultrasonics. For irregular and internal surfaces on a component, ultrasonics is very effective because it can reach where other mechanical removal means cannot gain access to the contaminated surfaces.

Where the contaminant comprises solids that are not dissolved by the cleaning fluid, ultrasonics also aids in removing these particles from the component surface. However, the cleaning fluid must wet the particles so that this fluid can then carry the particle away from the component surface.

The ultrasonics assists in the removal of the particle from the component and in the motion of the cleaning fluid as it carries the contaminant away from the component site. It is also possible that ultrasonics may increase the rate of chemical action in the dissolving of contaminants.

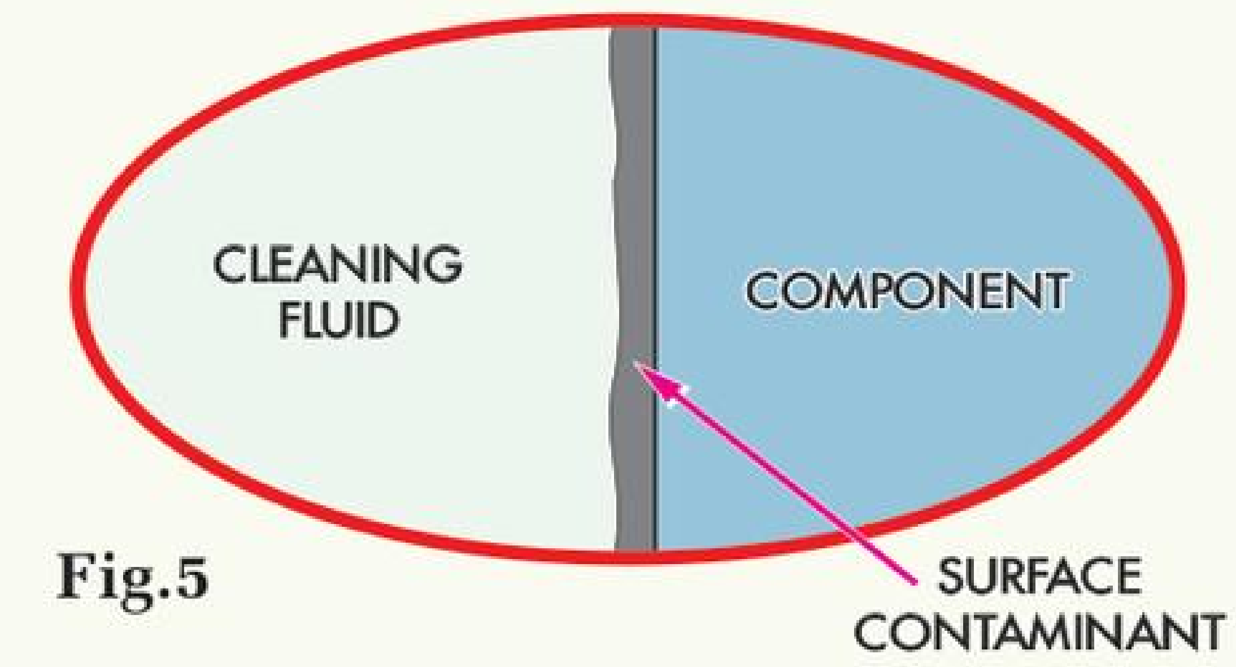

Fig.5

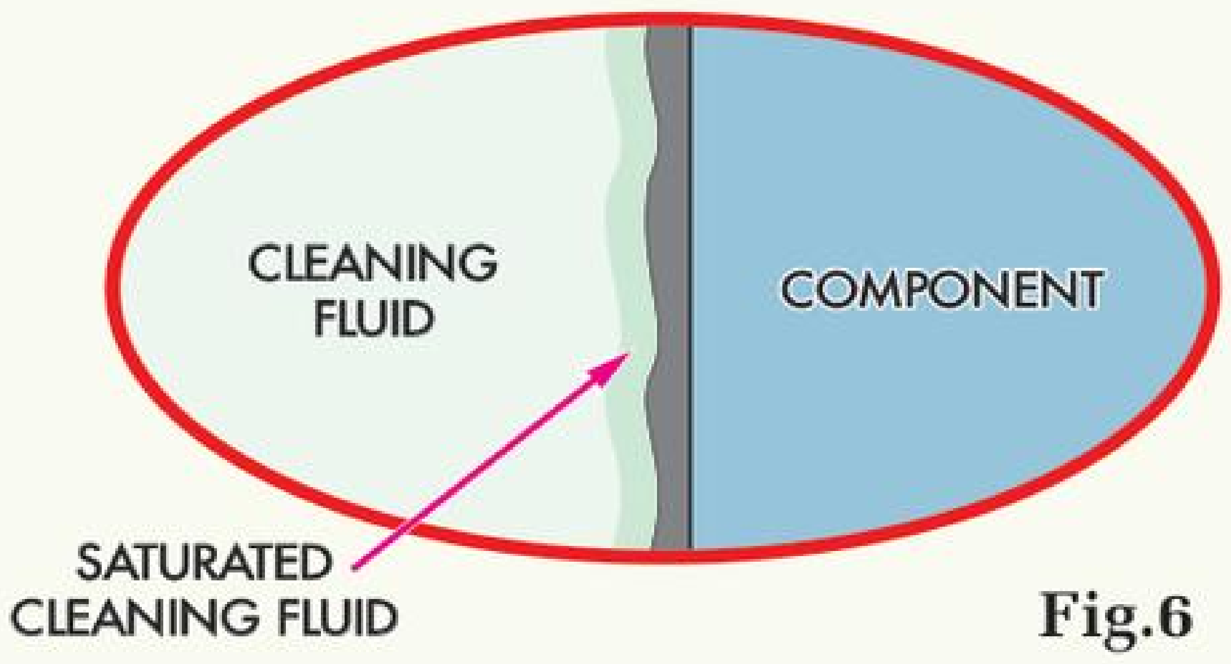

Fig.6

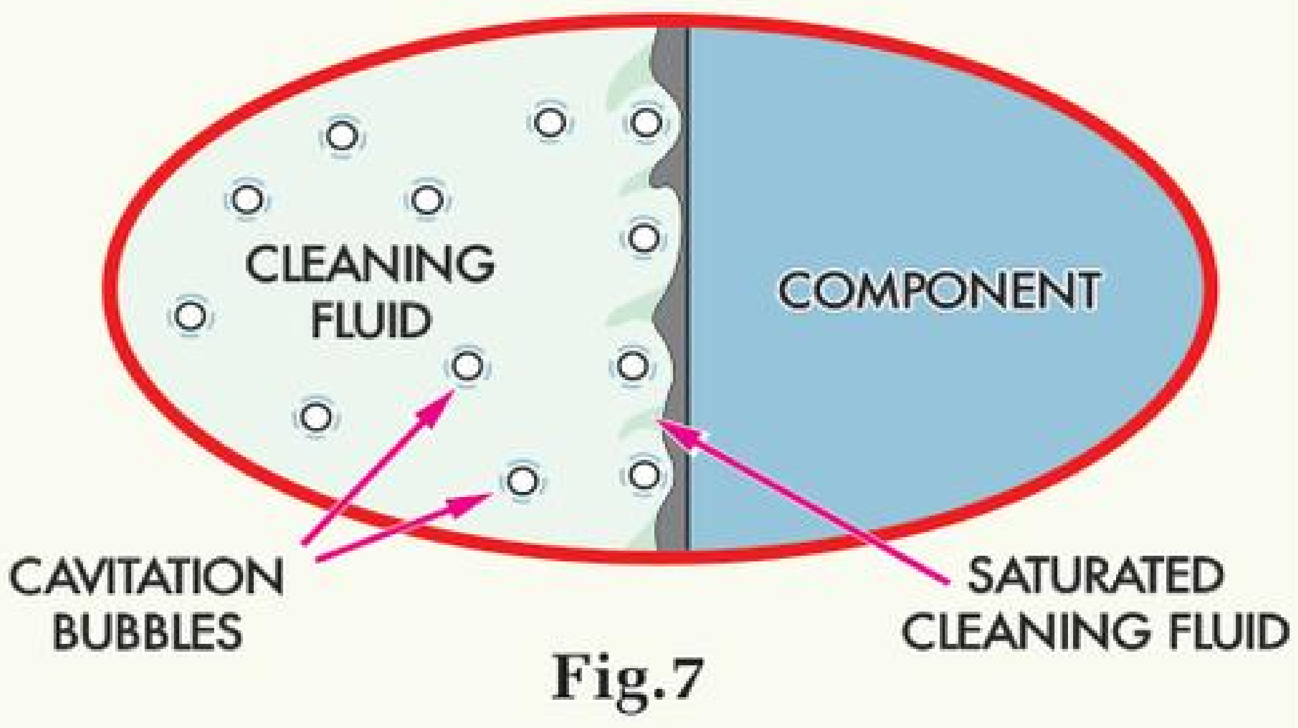

Fig.7

Finally, complete the assembly by installing IC1 and the fuse (make sure the power is *off*), then fit the case lid.

Bath time

When the ultrasonic transducer is directly inserted into the bath, the bath can be made of almost any suitable material ranging from plastics through to glass and metal.

For external attachment of the ultrasonic transducer, the bath can be made from stainless steel, aluminium or plastic that couples the ultrasonic vibration through into the fluid. Thinner materials couple the ultrasonics with less loss. The bath should have a flat side or base where the transducer can be attached. The material also needs to be compatible with the epoxy resin used to glue the transducer to the bath. Metals are the most compatible material.

Larger baths with more liquid will have a lesser cleaning effect than smaller containers with less fluid. A 200mm diameter or smaller cylindrical container, or a similar sized rectangular bath size could be used with up to one litre of fluid in the bath. This is ideal for the ultrasonic sensor and driver. Alternatively, a stainless steel kitchen sink can be pressed into service.

The fluid used in the bath can be water with a few drops of detergent as a wetting agent. Other fluids can be used, including methylated spirits. Cleaning effectiveness is greatly enhanced when the fluid is warmed.

Normal operation of the *Ultrasonic Cleaner* is where the frequency is cycled over the 19kHz to 42kHz range. First, set the timer control knob for up to 10-minutes. Pressing the start switch begins the cleaning cycle. The cleaning can be stopped at any time by rotating the timer potentiometer fully anticlockwise, or switching off power. Power is indicated with an LED, while cleaning operation is shown with a second LED. The running operation will show the LED with a small amount of flickering.

For stubborn, hard-to-clean components, you can set the driver mode to the alternative setting. To do this, switch off power and wait until the power LED is out. Then press the start switch and apply power. Hold the switch for a couple of seconds and then release the switch. This sets the alternative driver cycle that centres about 40kHz. Note that it is recommended that this alternative mode be *only used intermittently*, and for less than a few minutes because the MOSFET and transformer run hot during this cycle.

To return to the normal mode, first switch off power and wait again until the power LED is out. Then press the start switch and apply power. Hold the switch for a couple of seconds and then release the switch. This will return the cleaner to the normal driver cycle.

So how can you identify which cycle is running? The setting when the *Ultrasonic Cleaner* is first built is the normal cycle. For this cycle, the Running LED will flicker on and off and the transducer will emit its own distinctive audible sound. And yes, the transducer is ultrasonic, but some sound is heard as the transducer frequency is swept. Sub harmonics and the frequency modulation are audible. For the alternative cycle, the running LED will be virtually flicker-free and the audible sound will differ from the normal cycle mode. ***EPE***

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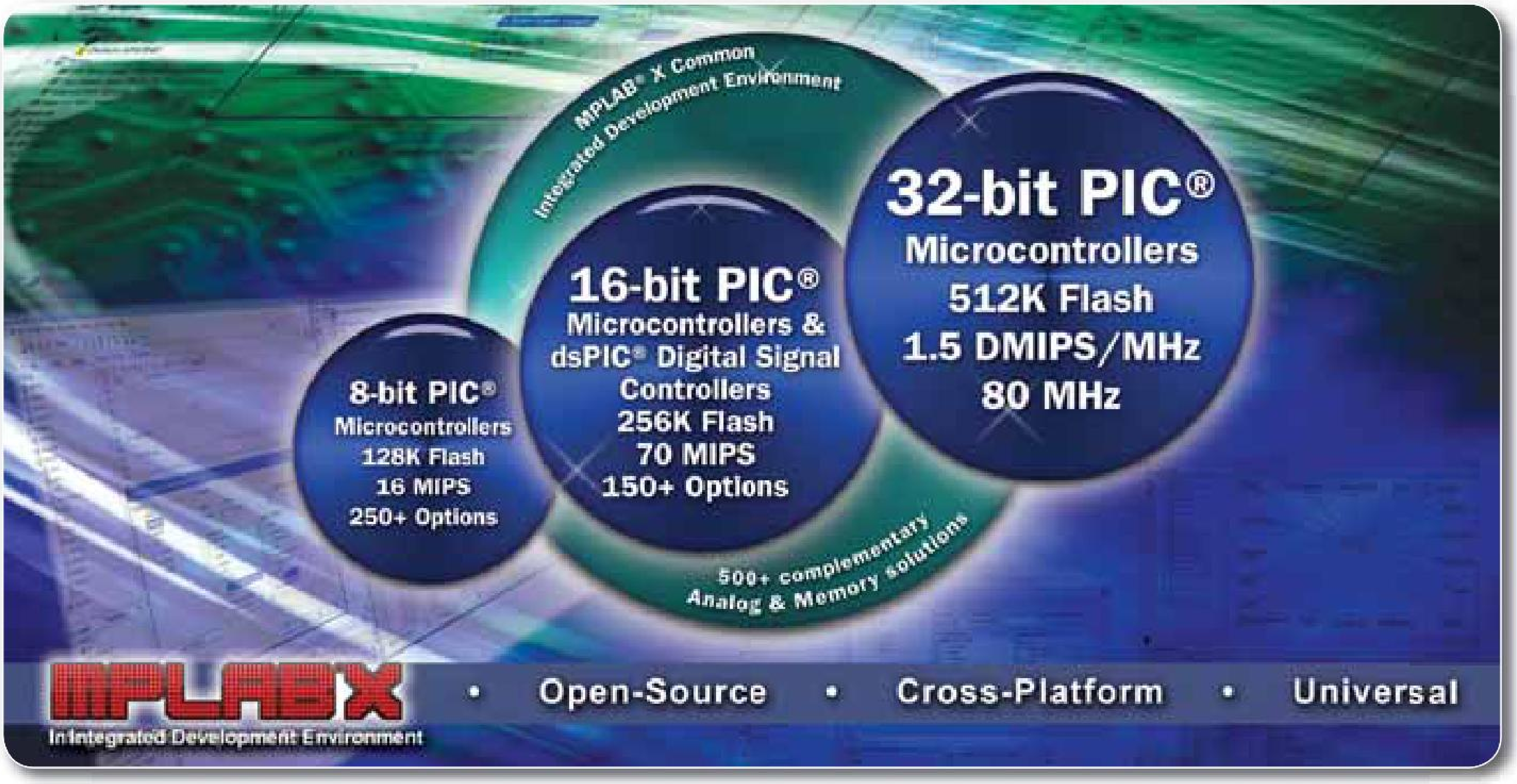
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TechnoTalk

Lightning Strikes

Mark Nelson

If someone had told Benjamin Franklin that a gizmo the size of a key fob was all he needed to detect lightning, do you think he would have believed this? More important, would you? Even more important, why would you wish to? Mark answers all three questions.

LIGHTNING is hardly popular; anyone who has suffered a strike close to home will know how easily it can kill hi-fi, video and computer equipment (and people) at a stroke. Is it an everyday occurrence? Not at the same place, but according to the Met Office, Britain sees more than 150 lightning strikes to ground each day, and on average the country sees six hits per square mile annually. In summer, the lion's share of thunderstorms occur in eastern England, while in winter the epicentre is Cornwall.

If you have property insurance, an 'All Risks' policy should cover the cost of replacing damaged equipment; a 'Fire and Special Perils' policy will not, so it's important to check for exclusions. Of course, a free replacement hard drive is no consolation if lightning has zapped your lifetime collection of MP3 music or the mission-critical data that you failed to back up offline, so how can you mitigate the risk?

Installing surge-arresting plugs and telephone line filters is a good idea. Modern protection devices are remarkably sophisticated, but even these don't guard against direct lightning hits, however, so don't be too judgmental if they fail to stop a 200 kilo-amp surge!

Here is the lightning forecast...

Would it help if you were able to predict lightning strikes with accuracy before they occurred? Britain's centre of excellence is the UK National Lightning Location Service, based at Capenhurst (near Chester), which since 1989 has been identifying the position of lightning strikes within the UK.

This information is supplied commercially to electricity companies in the UK and Eire, as well as to major industrial customers. The insurance industry uses the service too, for evaluating risk to property and for validating insurance claims by referring to records of activity.

The service is provided by EA Technology Ltd and offers 'live' displays of lightning activity, historic data reports, and lightning strike density plots. The firm has also developed a novel system that gives up to two hours' prediction of the location of individual lightning strikes. This can locate strikes typically within 1km to a time accuracy of 0.01 seconds. The number of lightning strikes that will affect an area can be predicted with an accuracy as high as a remarkable 85 per cent.

For those with no budget to pay for this service, there are non-commercial alternatives. The acclaimed Isle of Wight Weather station (**www.isleofwightweather.co.uk/**) monitors current lightning and thunderstorm activity in the UK, and you can see the results live without charge.

Personal services

Some people claim they can tell when it's about to thunder, probably because they have just noticed thunder flies (lightning bugs) on the wing. Personal lightning detectors do exist, and by all accounts they are increasing in popularity among individuals and professionals. Similar in looks and size to a radiopager (remember those?), personal lightning detectors are used by golfers, campers, sports officials, and others who work outdoors.

They work by detecting the electromagnetic pulse emitted by a lightning strike, the strength enabling the gadget to estimate the distance of the detected strike. The more sophisticated models can also calculate and indicate the direction of the storm's movement relative to its position (approaching, departing or stationary). Not surprisingly, these devices do have limitations, all they register is lightning somewhere in the area. They are also susceptible to interference from other appliances, resulting occasionally in false positives.

Intelligent algorithm

These shortcomings are mitigated by a brand-new integrated circuit, heralded as the world's first lightning sensor chip. Targeted specifically at low-power, portable applications by the manufacturer Austria Micro Systems (**austriamicrosystems.com**), the sensor is capable of detecting lightning up to 40km (25 miles) away and employs an embedded intelligent algorithm that produces an estimated distance-to-storm calculation from 40km down to 1km, while rejecting disturbances from man-made signals such as motors.

Named after American innovator, Benjamin Franklin, the new sensor provides people with advanced warning of approaching electrical storms by giving them additional time to take shelter. Under the lid, the sensor uses a sensitive RF receiver that detects the electrical emissions from lightning activity. A highly sophisticated proprietary algorithm converts the RF signal into an estimation of the distance to the head of the storm.

Target markets for the new product include outdoor recreation and also in-building equipment such as uninterruptible power supplies (UPS), power conditioners, telecom equipment, intelligent networks and smart grids needing early detection for use in surge damage prevention.

Minimalist needs

Designed for low-power operation, consuming only 60μA in listening mode, the 16-pin package measures just 4mm × 4mm. Typically, it requires only a simple microcontroller and seven other passive components allowing it to fit easily in a space about the size of a car keyfob remote. Extensive field trials conducted in Finland and the US indicate that the new mini sensor shows good correlation when compared to larger, more complex systems.

Bruce Ulrich, Wireless Product Line Director at austriamicrosystems sums up, 'It is now possible to protect both humans and equipment from harm by providing early warning of impending danger. I have personally seen baseball teams in danger because the umpire did not have enough information to call off the game because of lightning...'

Hobbyist activities

If you feel like getting involved in lightning observation, you might just be able to blag a sample device if you can demonstrate a convincing application (take a look at: **www.austriamicrosystems.com/Lightning-Sensor/AS3935**).

Beyond this there's plenty of information on the Web, such as a lightning detection guide (**www.lightningsafety.noaa.gov/resources/Lightning_Detection.pdf**), the amateur lightning detection network (**www.lightningradar.net/**) and the Lightning Ring (**www.lightningring.com/**).

Skyview Systems Ltd, based in Sudbury, Suffolk, offers a wide range of hardware and software (**www.skyview.co.uk/dept1/acatalog/Lightning_Detectors.html**).

Electrolytic capacitor reformer and tester

Got a bunch of old electrolytic capacitors you'd like to use . . . but don't know if they are any good? Or do you need to reform the electrolytics in an old valve amplifier or vintage radio set?

This Electrolytic Capacitor Reformer and Tester will do the job for you, at any of 11 different standard voltages from 10V to 630V.

Part 1: by JIM ROWE

IN ADDITION, it provides the ability to apply the selected test voltage for any of seven periods, ranging from 10 seconds to 60 minutes.

Thus you can use it for 'reforming' electrolytic capacitors that have developed high leakage and high impedance due to years of inactivity. Also, it can be used to test the leakage of virtually all capacitors at or near their rated voltage.

Of course, we have to state that not all old electrolytics can be restored – they can't. Some will have very high leakage due to contamination of the can seal or breakdown of the electrolyte, some will have just dried out. In those cases, you cannot do anything to resurrect them, but in many cases you will be able to restore and reuse capacitors that have not been used for many years, if not decades.

Some very old caps (1960s vintage) we had took several hours to come good, while others, made in more recent years, were good within a few minutes.

Most high voltage (ie, 250V and above) capacitors should be capable of being reformed to the extent that their leakage current drops to around 3mA or less.

Damage limitation

The *Reformer* circuit is designed so that no damage can occur if the capacitor connected to it is short circuit or has very high leakage, or is even connected back-to-front (ie, with reverse polarity). Furthermore, even if the capacitor leakage is very high, the output current is limited so that the maximum dissipation in the capacitor is no more than 2W.

This means that some capacitors might get warm while they are being reformed, but none will get so hot that they are in danger of swelling up and 'letting the smoke out'.

That's a good thing, because electrolytic capacitor smoke is particularly foul-smelling! And as any serviceman will tell you, the gunk (electrolyte) inside is particularly nasty if it escapes with the smoke.

The *Electrolytic Capacitor Reformer and Tester* is housed not in a traditional instrument case or box, but in a standard plastic storage organiser case, which, together with a microswitch interlock, provides a safe compartment for the capacitor when it has high voltage applied. Another compartment provides handy storage for the switchmode 12V plugpack.

Opening the lid of the case means that no voltage is applied to the capacitor – until the lid is closed – but perhaps even more importantly, opening the lid safely and quickly discharges the capacitor so there is no chance of a

WARNING: SHOCK HAZARD!

Because the voltage source in this instrument can be set to provide quite high DC voltages (up to 630V) and can also supply significant current (tens of milliamps), it does represent a potential hazard in terms of electric shock. We have taken a great deal of care to ensure that this hazard is virtually zero if the instrument is used in the correct way – ie, with the lid closed and secured – even to the extent of quickly discharging any capacitor when the lid is opened.

However, if the safety switching is bypassed, especially when the unit is set to one of the higher test voltages, it is capable of giving you a very nasty 'bite' should you become connected across the test clips or a charged high voltage capacitor. There are some situations where such a shock could potentially be lethal.

Do NOT bypass the safety features included in this design. We don't want to lose any readers to electrocution.

Most hobbyists would have collected many old electros over the years (maybe not as old as some of these!) – but are they any good, and can they be resurrected?

nasty electric shock – for you or anyone else. A charged 630V capacitor with its leads exposed is not something to be trifled with!

With the lid closed, you can select the test voltage and the period of reform/testing, and view the 2-line LCD which shows the capacitor voltage, leakage current and the time elapsed.

Circuit design

Electrolytic Capacitor Reformer and Tester is based on the simpler unit described in the November 2011 issue of *EPE*, but with a much bigger selection of test voltages, plus the in-built test timer, which allows the test voltage to be applied for as long as 60 minutes.

Commercial capacitor leakage current meters/reformers are available, but they tend to be fairly expensive (well over £650) and we don't believe any of them incorporate a safety interlock to avoid the possibility of electric shock. With ours, you have a choice of eleven different standard test voltages: 10V, 16V, 25V, 35V, 50V, 63V, 100V, 250V, 400V, 450V and 630V. These correspond with the rated voltages of most electrolytic capacitors which have been available for the last 30 years or so.

If you have an 'oddball' capacitor with a different working voltage, simply select the next voltage down.

(In fact, in the vast majority of cases selecting the next voltage up won't do the capacitor any harm either, because most capacitors, especially electrolytics, can stand a short-term higher peak voltage than their working voltage, hence the labelling – eg, 400VW, 500VP).

With any of these test voltages applied to a 'test capacitor', you can read its leakage current on the 2-line × 16-character backlit LCD screen, with two automatically selected current ranges: 0 to 200µA or 0 to 20mA. You can also read the voltage which

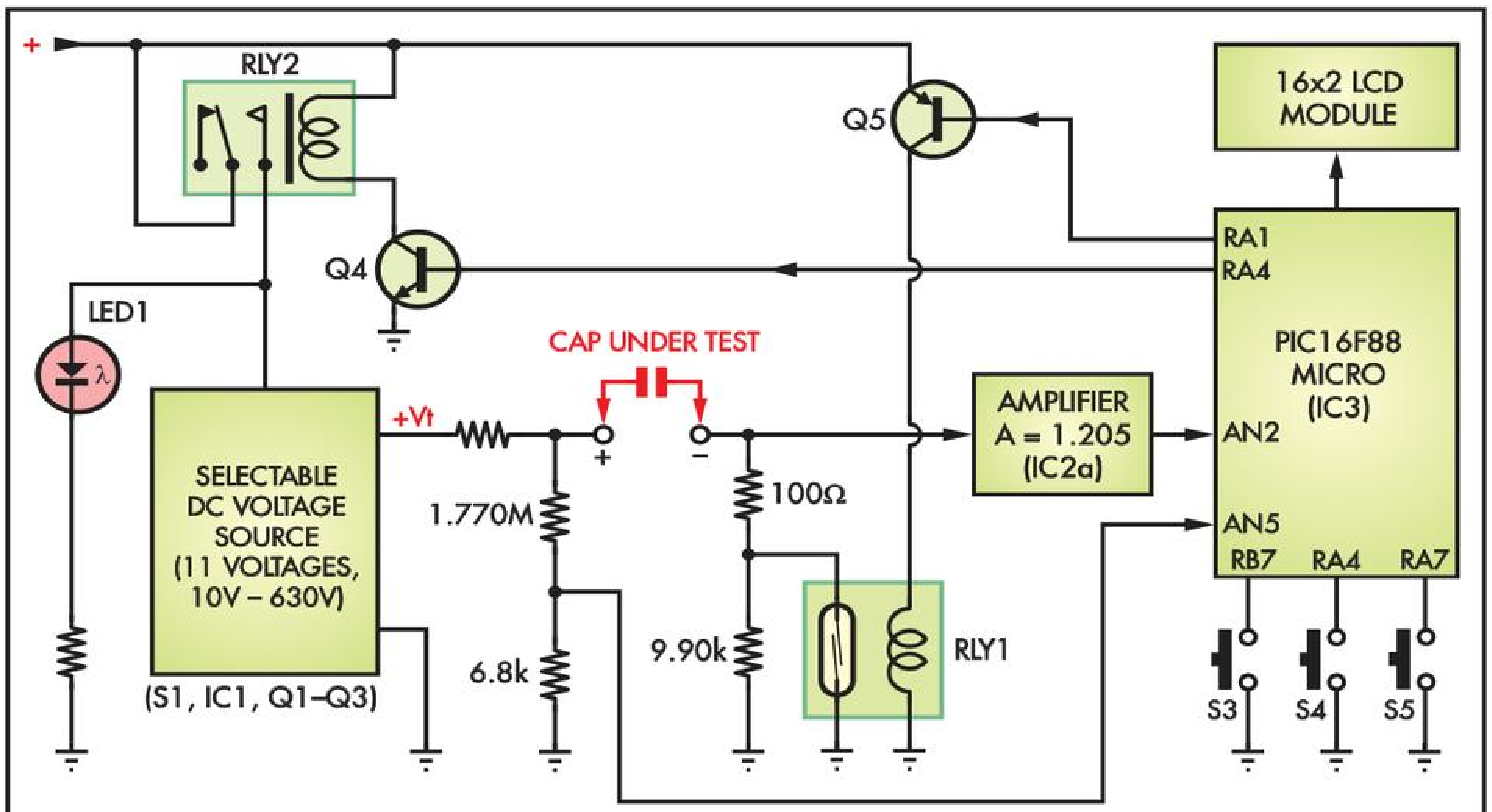


Fig.1: block diagram of the Electrolytic Capacitor Reformer and Tester. Not shown here is the safety interlock microswitch and discharge resistors.

appears across the capacitor at any time in the procedure.

Also important, is that for reforming capacitors you have the choice of ten test periods: 10 seconds, 30 seconds, 1 minute, 3 minutes, 10 minutes, 30 minutes or 60 minutes.

How it works

Essentially, the *Reformer's* operation is quite straightforward, as you can see from the block diagram of Fig.1. This is broadly very similar to the design in our November 2011 issue.

There are only two functional circuit sections, one being a selectable DC voltage source (on the left) which generates one of 11 different preset test voltages when power is applied to the voltage source (actually a DC-to-DC converter) via relay RLY2, controlled by the PIC micro (IC3) via transistor Q4. This test voltage is applied to the positive terminal of the capacitor via a protective current-limiting resistor and a microswitch, whose purpose we will look at shortly.

The second functional circuit section is on the right in Fig.1, and combines a digital meter, which is used to measure any direct current passed by the capacitor under test, and the voltage appearing across the capacitor. There is also a digital timer which controls the DC test voltage source via Q4 and RLY2. The PIC micro (IC3) forms the 'brains' of this section.

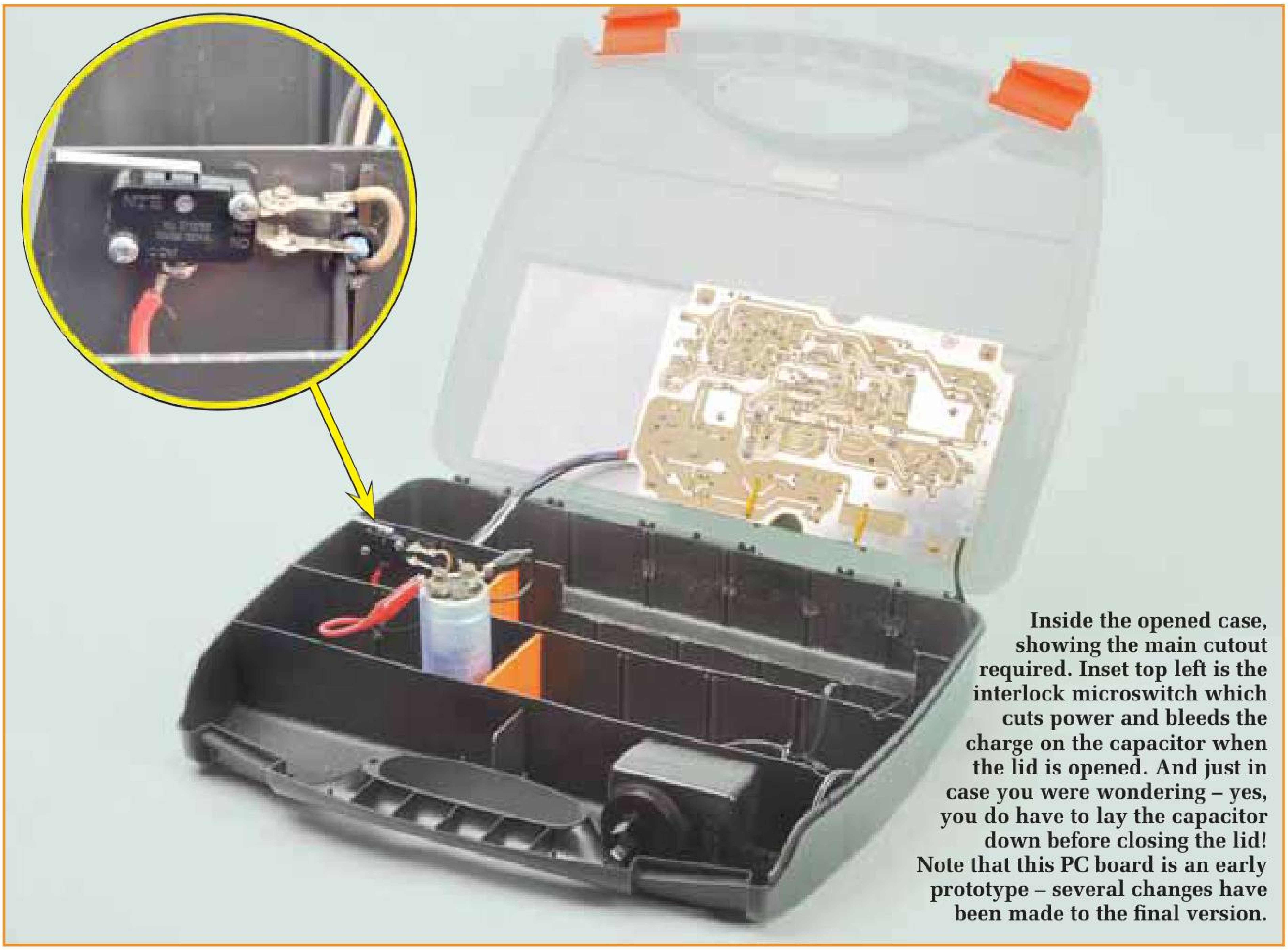
Voltmeter

We use IC3 as a voltmeter to make the current measurement because any current passed by the capacitor flows down to ground via the 100Ω resistor, either alone or with the 9.90kΩ resistor in series. The resistor(s) therefore act as a current shunt, and its voltage drop is directly proportional to the current flowing through the capacitor. The meter measures the voltage across the resistor(s) and is arranged to read directly in terms of current.

We also use IC3 to measure the voltage across the capacitor for the duration of the leakage test or reforming period. That way, you can keep track of the leakage current and the voltage at any time. For a good capacitor, the voltage across it will rise while the leakage current steadily reduces.

The reason for relay RLY1 and the 9.90kΩ resistor, which it effectively switches in series with the 100Ω resistor, is that this gives the digital current meter two ranges. This allows it to read leakage currents down to less than 100nA (0.1μA), while also coping with charging and/or leakage currents of up to 20mA or thereabouts.

Before the micro (IC3) begins a test by turning on transistor Q4 and relay RLY2 to apply power to the test voltage source, it first turns on transistor Q5 and relay RLY1 to short out the 9.90kΩ resistor, giving the effective current shunt



Inside the opened case, showing the main cutout required. Inset top left is the interlock microswitch which cuts power and bleeds the charge on the capacitor when the lid is opened. And just in case you were wondering – yes, you do have to lay the capacitor down before closing the lid! Note that this PC board is an early prototype – several changes have been made to the final version.

resistance a value of 100Ω, which gives a 0 to 20mA range for the capacitor's charging phase.

Only when (and if) the measured current level falls below 200μA does it switch off Q5 and RLY1, increasing the total shunt resistance to 10kΩ and thus providing a 0 to 200μA range for more accurate measurement of any residual leakage current.

So that's the basic arrangement. Pushbutton switches S3 to S5 are used to select the test time period and also to begin a test, or end it prematurely. LED1 is used to indicate when RLY2 has applied power to the DC voltage source, and when the test voltage is present across the capacitor test terminals.

The reason for the resistor in series with the output from the test voltage source is to limit the maximum current that can be drawn from the source in any circumstances.

This prevents damage to either the voltage source or the digital metering sections in the event of the capacitor under test having an internal short circuit. It also protects the 9.90kΩ shunt resistor and the digital voltmeter section from overload when a capacitor (especially one of high value) is initially charging up to one of the higher test voltages.

In the full circuit you'll find that this series resistance has a total value of 10.4kΩ, which was chosen to limit the maximum voltage which can ever appear at the input of the voltmeter's input amplifier (IC2a) to just over 6V, even under short-circuit conditions and with the highest test voltage of 630V.

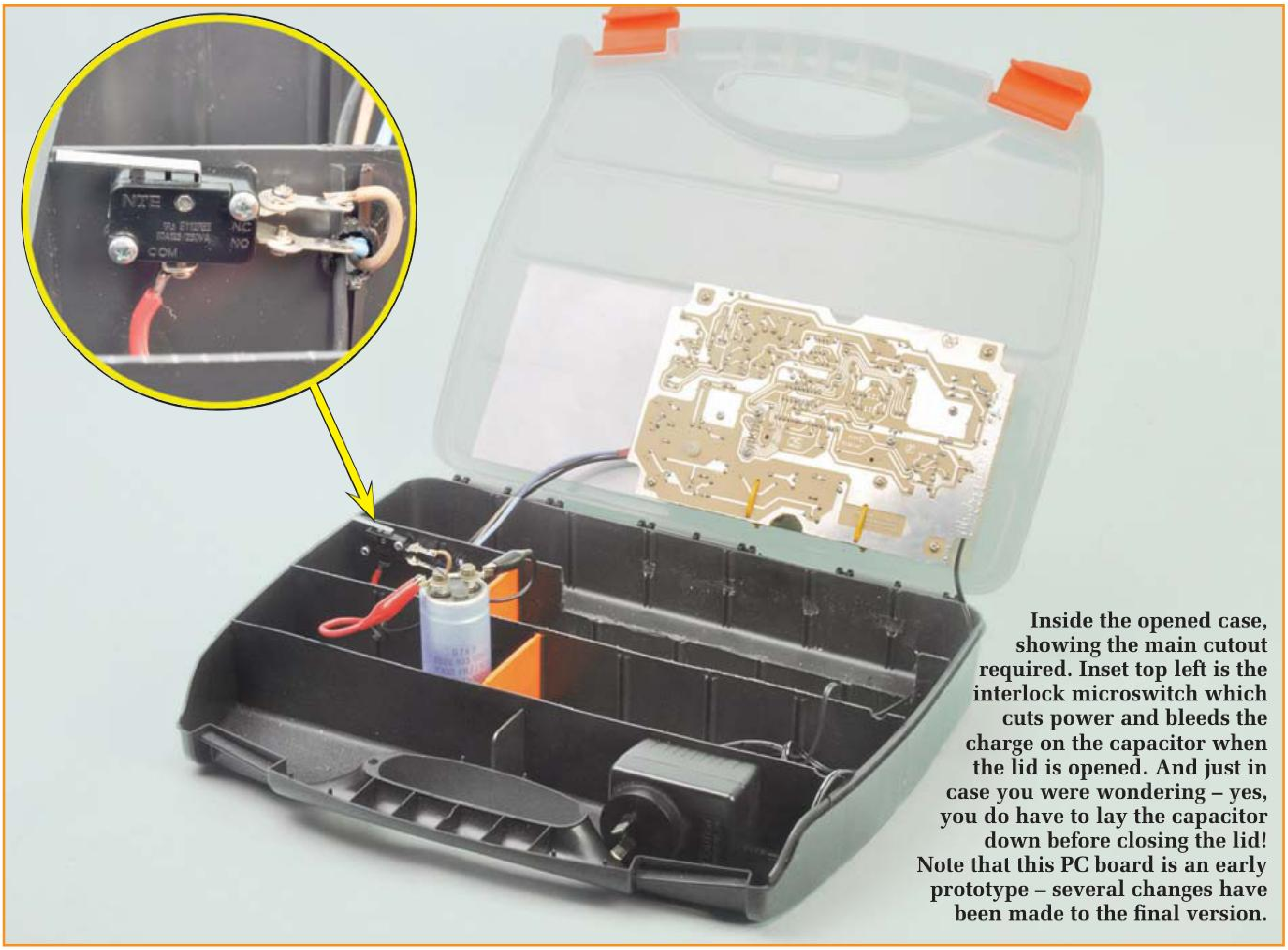
It is also used to limit the current when the instrument is being used for reforming electrolytics.

Circuit description

Now let's have a look at the full circuit diagram of the *Electrolytic Capacitor Reformer and Tester* (Fig.2). The selectable DC voltage source is again on the left, based around IC1 – an MC34063 DC/DC conversion controller IC.

It is used here in a step-up or 'boost' configuration in conjunction with driver transistors Q1 and Q2, switching transistor Q3, autotransformer T1 and fast switching diode D4. We vary the circuit's DC output voltage by varying the ratio of the voltage divider in the converter's feedback loop, connecting from the cathode (K) of D4 back to IC1's pin 5 (where the voltage is compared with an internal 1.25V reference).

The four series-connected 75kΩ resistors, together with trimpot VR1, form the top arm of the feedback divider, while the 100kΩ resistor from pin 5 to ground forms the fixed component of the lower arm. These give the voltage source its lowest output voltage of close to 10.5V, which is the converter's output voltage when selector switch S1 is in the '10V' position.



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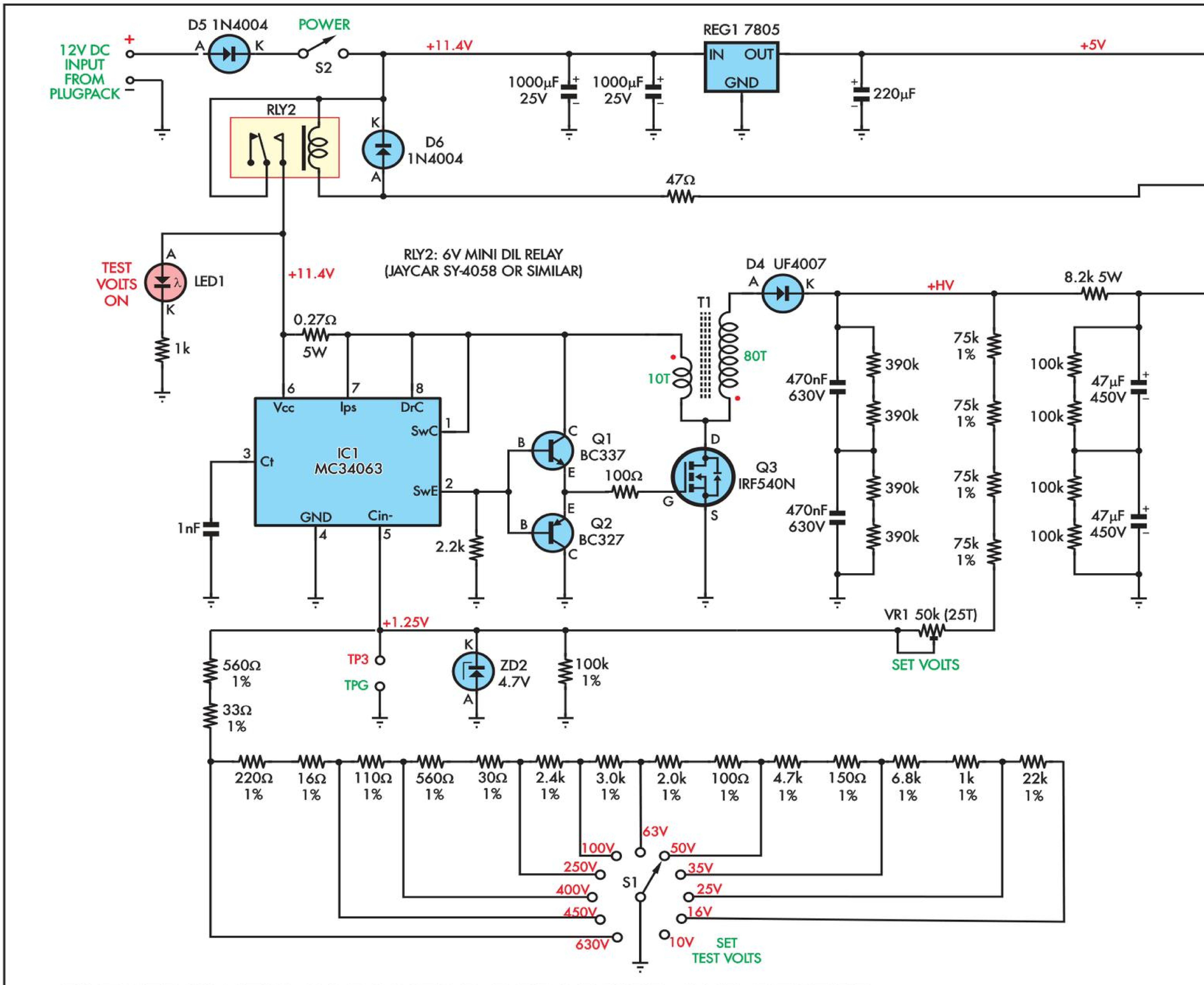

12V DC INPUT FROM PLUGPACK
D5 1N4004
POWER
S2
+11.4V
1000µF 25V
1000µF 25V
REG1 7805
IN
OUT
GND
220µF
+5V
RLY2
D6 1N4004
47Ω
TEST VOLTS ON
LED1
1k
RLY2: 6V MINI DIL RELAY (JAYCAR SY-4058 OR SIMILAR)
+11.4V
0.27Ω 5W
D4 UF4007
T1
10T
80T
+HV
8.2k 5W
Vcc
Ips
DrC
SwC
Ct
IC1 MC34063
SwE
GND
Cin-
1nF
Q1 BC337
Q2 BC327
100Ω
Q3 IRF540N
2.2k
470nF 630V
390k
75k 1%
100k
47µF 450V
+1.25V
VR1 50k (25T)
SET VOLTS
560Ω 1%
33Ω 1%
TP3
TPG
ZD2 4.7V
100k 1%
220Ω 1%
16Ω 1%
110Ω 1%
560Ω 1%
30Ω 1%
2.4k 1%
3.0k 1%
2.0k 1%
100Ω 1%
4.7k 1%
150Ω 1%
6.8k 1%
1k 1%
22k 1%
S1
100V
63V
50V
35V
250V
400V
25V
450V
16V
630V
10V
SET TEST VOLTS

ELECTROLYTIC CAPACITOR REFORMER AND TESTER

When S1 is switched to any of the other positions, additional resistors are connected in parallel with the lower arm of the feedback divider, to increase its division ratio and hence increase the converter's output voltage. For example, when S1 is in the '16V' position, all of the series-connected resistors in the string between the various positions of S1 are in parallel with the 100kΩ resistor, increasing the division ratio to increase the converter's regulated output voltage to 16.25V.

The same kind of change occurs in all of the other positions of S1, producing the various preset output voltages shown. Although the test voltages shown are nominal, if you use the specified 1% tolerance resistors for all of the divider resistors they should all be within ±4% of the nominal values, because the 1.25V reference inside the MC34063 is accurate to within 2%.

IC1 operates only when the 11.4V supply rail is connected to it via relay RLY2, under the control of micro IC3. The converter circuit then operates and generates the desired test voltage across the two 470nF/630V metallised polyester reservoir capacitors, connected in series, with their voltage-sharing resistors in parallel. At the same time, LED1 is illuminated, to warn you that the test voltage will be present at the test terminals.

Note that the test voltage present at the top of the feedback divider is not fed directly to the positive test connector, but is first fed through a low-pass RC filter formed by the 8.2kΩ 5W resistor and the series-connected 47µF/450V capacitors (which again have voltage-sharing resistors in parallel).

This filter is to smooth out any ripple present in the output of the voltage source/converter. The filtered test voltage is then made available at the positive test terminal via a 2.2kΩ 5W

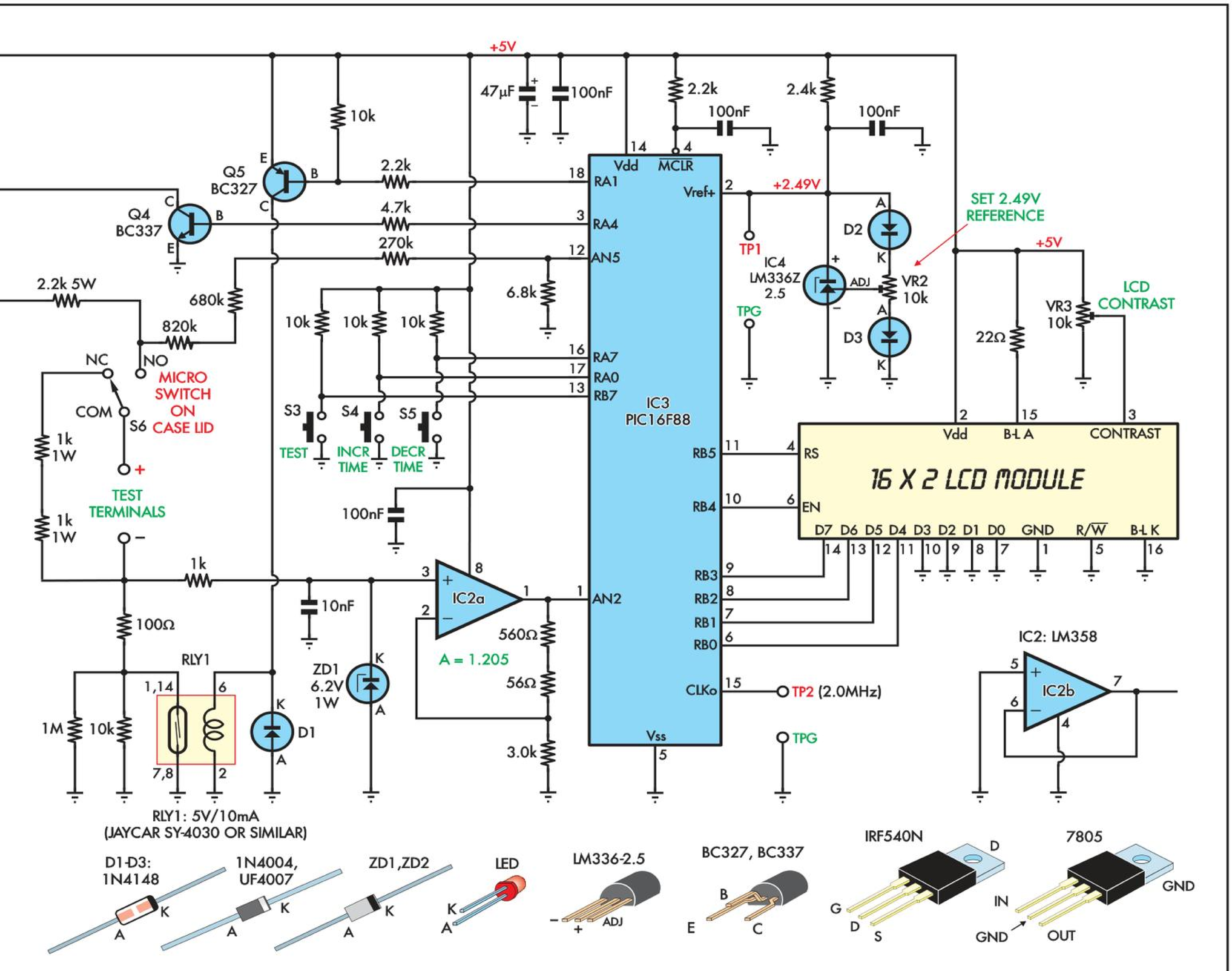

+5V
47µF
100nF
10k
2.2k
2.4k
100nF
100nF
Q5
BC327
Q4
BC337
E
B
C
2.2k
4.7k
270k
2.2k 5W
680k
820k
6.8k
10k
10k
10k
NC
NO
COM
S6
MICRO SWITCH ON CASE LID
1k 1W
1k 1W
TEST TERMINALS
+
–
S3
S4
S5
TEST
INCR TIME
DECR TIME
100nF
1k
100Ω
10nF
RLY1
1,14
6
7,8
2
1M
10k
D1
ZD1 6.2V 1W
K
A
IC2a
A = 1.205
560Ω
56Ω
3.0k
Vdd
MCLR
RA1
RA4
AN5
RA7
RA0
RB7
IC3 PIC16F88
Vref+
RB5
RB4
RB3
RB2
RB1
RB0
AN2
CLKo
Vss
+2.49V
TP1
IC4 LM336Z 2.5
ADJ
TPG
D2
D3
VR2 10k
SET 2.49V REFERENCE
VR3 10k
LCD CONTRAST
22Ω
16 X 2 LCD MODULE
RS
EN
Vdd
B-L A
CONTRAST
D7 D6 D5 D4 D3 D2 D1 D0 GND R/W B-L K
TP2 (2.0MHz)
TPG
IC2: LM358
IC2b
RLY1: 5V/10mA
(JAYCAR SY-4030 OR SIMILAR)
D1-D3: 1N4148
1N4004, UF4007
ZD1,ZD2
LED
LM336-2.5
BC327, BC337
IRF540N
7805
G
D
S
IN
GND
OUT

Fig.2: similar to the block diagram, the circuit is divided into two distinct sections – the high voltage generation on the left side and the reforming/reading/metering section on the right, which itself is under the control of a PIC microcontroller. Don't depart from this circuit diagram – a lot of effort has gone into making it safe!

series resistor, which together with the 8.2kΩ 5W series resistance of the filter forms the protective current-limiting resistance shown in Fig.1.

Charged electros can be lethal!

Before the test voltage is fed to the capacitor's positive test connector, it first has to pass through microswitch S6, which is attached to the case so that it switches when the case lid is opened. Normally, (ie, with the lid closed) the test voltage is connected, but when the lid is opened, the test capacitor's positive terminal is connected to its negative terminal via two 1kΩ, 1W resistors, which will discharge even the largest high voltage capacitors normally encountered in less than a second. Two 1W resistors are used to obtain a sufficiently high voltage rating for the highest value test setting.

Of course, very high value lower-voltage capacitors will take much longer to discharge (as much as a few seconds or so) but these are not considered as dangerous to life and limb.

It is important for your safety (and more importantly, the safety of others) that the microswitch is not left out nor bypassed or worse, the circuit is built into a case which does not have a hinged lid allowing this form of protection. The circuit is perfectly safe as described.

Wiring external to the PC board (ie, the high voltage wiring) ***MUST*** be made with 250V AC-rated cable. The easiest place to get such cable is from a surplus flexible mains lead. In fact, you might be lucky enough to find that you have some with red and black insulated wires (which are needed for the test capacitor connections) and newer ones with brown and blue insulated wires (ideal for the connections between PC board and microswitch). We wouldn't use the green or green/yellow wiring for ANY purpose except earth wiring.

Parts List – Electrolytic Reformer and Tester

1	PC board, code 861, available from the *EPE PCB Service,* 224mm × 120mm
1	Trojan TJW0510 38cm Storage Organiser
1	Front panel label, 320mm × 120mm, laminated
1	16×2 LCD module with backlighting **(Jaycar QP-5516)**
1	Mini DIL reed relay, SPST with 5V coil
1	Mini DIL relay, SPDT with 6V coil
1	SPDT 250V 10A microswitch **(Jaycar SM-1040 or equivalent)**
2	19mm square TO-220 finned heatsinks
1	Ferrite pot core pair, 26mm OD with bobbin to suit
1	25mm long M3 nylon screw with nut and flat washer
1	1m length of 0.8mm diameter enamelled copper wire
1	10m length of 0.25mm diameter enamelled copper wire
1	Single pole 12-position rotary switch (S1)
1	Instrument knob, 16mm with grub screw fixing
1	SPDT mini toggle switch, panel mtg (S2)
3	SP Momentary pushbutton switches, panel mounting (S3-5)
18	6mm long M3 machine screws, pan head
4	25mm long M3 tapped spacers
4	12mm long M3 tapped nylon spacers (or two – see text)
3	nylon flat washers (only for QP-5516 module – see text)
2	M3 nuts
1	7×2 length DIL socket strip, OR 16-way length SIL socket strip (see text)
1	7×2 length DIL pin strip, OR 16-way length SIL pin strip (see text)
1	18-pin IC socket
2	8-pin IC sockets
10	PC board terminal pins, 1mm diameter
2	100mm long nylon cable ties

Semiconductors

1	MC34063 DC/DC converter controller (IC1)
1	LM358 dual op amp (IC2)
1	PIC16F88 programmed microcontroller (IC3)
1	LM336Z 2.5V reference (IC4)
1	7805 +5V regulator (REG1)
2	BC337 *NPN* transistor (Q1,Q4)
2	BC327 *PNP* transistor (Q2,Q5)
1	IRF540N 100V/33A MOSFET (Q3)
1	6.2V Zener diode (ZD1)
1	4.7V Zener diode (ZD2)
1	5mm red LED (LED1)
3	1N4148 100mA signal diode (D1,D2,D3)
1	UF4007 ultrafast 1000V/1A diode (D4)
2	1N4004 400V/1A rect. diode (D5,D6)

Capacitors

2	1000µF 25V radial elect.
1	220µF 16V radial elect.
1	47µF 16V radial elect.
2	47µF 450V radial elect.
2	470nF 630V metallised polyester
2	100nF MKT metallised polester
2	100nF multilayer monolithic ceramic
1	10nF MKT metallised polyester
1	1nF disc ceramic

Resistors (0.25W 1% metal film unless specified)

1	1MΩ	1	820kΩ	1	680kΩ	4	390kΩ	1	270kΩ
5	100kΩ	4	75kΩ	1	22kΩ	1	8.2kΩ 5W	5	10kΩ
2	6.8kΩ	2	4.7kΩ	2	3.0kΩ	1	2.2kΩ 5W	2	2.4kΩ
3	2.2kΩ	1	2.0kΩ	2	1kΩ 1W	3	1kΩ	3	560Ω
1	220Ω	1	150Ω	1	110Ω	2	100Ω	1	56Ω
1	47Ω	1	33Ω	1	30Ω	1	22Ω	1	16Ω
1	0.27Ω 5W								
1	50kΩ 25T vertical trimpot (VR1)								
2	10kΩ mini horizontal trimpot (VR2,VR3)								

Software

All software program files will be available from the *EPE* website at **www.epemag.com**.

Although we do not supply pre-programmed microcontrollers, you can purchase the programmed micro featured in this project from: **parts@siliconchip.com.au**

Voltage and current metering

Now let us look at the digital metering and control section, which is virtually all of the circuitry below and to the right of the negative test terminal. The 100Ω resistor and paralleled 1MΩ and 10kΩ resistors connected between the negative test terminal and ground correspond to the current shunts shown in Fig.1, with the contacts of reed relay RLY1 used to change the effective shunt resistance for the meter's two ranges.

For the 20mA 'charging phase' range, RLY1 is energised via Q5 and connects a short circuit across the parallel 1MΩ/10kΩ combination resistors, making the effective shunt resistance 100Ω. But for the more sensitive 200µA range, RLY1 is turned off, opening its contacts and connecting the parallel 1MΩ/10kΩ resistors in series with the 100Ω resistor to produce an effective shunt resistance of 10kΩ.

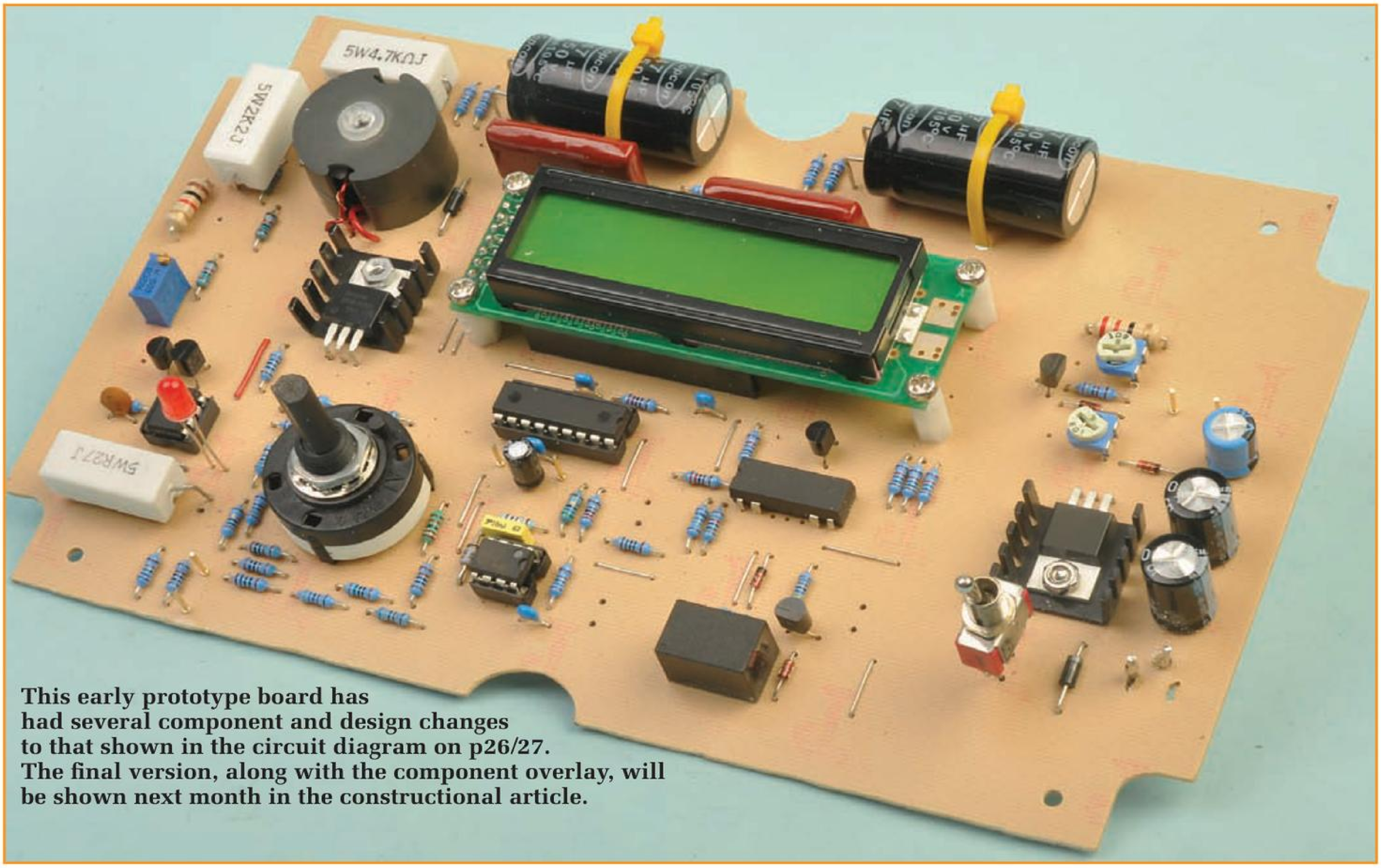
As you can see, the voltage drop across the shunt resistance (as a result of any current passed by the capacitor under test) is passed to the non-inverting input of IC2a, one half of an LM358 dual op amp. IC2a is configured as a DC amplifier with a voltage gain of 1.205 times, feeding the AN2 analogue input of IC3, the PIC16F88 microcontroller, which forms the 'heart' of the metering/control section.

Reference voltage

IC3 takes its measurements of the amplified current shunt voltage from IC2a by comparing this voltage with a reference voltage of 2.490V fed into pin 2 of IC3. The reference voltage is derived from the regulated +5V supply line via voltage reference IC4, an LM336Z device, which is provided with a voltage trim circuit using diodes D2, D3 and trimpot VR2. These are used to set its voltage drop to exactly 2.490V, where it displays a near-zero temperature coefficient.

In fact, IC3 takes a sequence of 10 measurements at a time and calculates the average of the 10 readings to reduce 'jitter' caused by noise transients. It then does mathematical scaling to arrive at the equivalent current readings, which it displays on the 16x2 LCD module.

IC3 also monitors the voltage across the capacitor via a voltage divider feeding its AN5 input, pin 12.


This early prototype board has had several component and design changes to that shown in the circuit diagram on p26/27. The final version, along with the component overlay, will be shown next month in the constructional article.

Timer function

As mentioned earlier, pushbutton switches S3 to S5 are used to select the test time period to be used, and also to begin testing a capacitor. Switch S4 is used to increase the test period time, while S5 is used to decrease it. Then, when the user has set S1 for the correct test voltage and has selected the test time period using S4 and S5, testing is begun by pressing switch S3.

IC3 then turns on transistor Q5 and relay RLY1 to set the metering circuit for the 10mA range, after which it turns on Q4 and RLY2 to feed power to the test voltage converter (and LED1). It also starts a software timer to control how long the test voltage is to be applied.

While the test is being carried out, the metering section takes voltage and current readings and displays these on the LCD module, changing down to the 0 to 200μA range automatically if the measurements drop below 0.2mA. When the selected test time period ends or the user presses S3 again to end the test prematurely, IC3 switches off the test voltage source. The voltage and current measurements continue however, so you can monitor the current decay as the test voltage drops to zero.

Zener diode ZD1 is included in the metering circuit to protect pin 3 input of IC2a from damage, due to accidental application of a negative or high positive voltage to the negative test terminal (from a previously charged capacitor, for example). On the other hand, diode D1 is included to protect transistor Q5 from damage due to any back EMF 'spike' from the coil of RLY1 when it is de-energised.

Trimpot VR3 allows the contrast of the LCD module to be adjusted for optimum visibility. The 22Ω resistor connecting from the +5V supply rail to pin 15 of the LCD module is to provide current for the module's LED back-lighting.

IC1 and the selectable DC voltage source operate directly from the 12V DC supply line (via polarity protection diode D5 and, of course, power switch S2), while the rest of the circuit operates from a regulated 5V rail which is derived from the battery/plugpack via REG1, a 7805 3-terminal regulator.

That's basically it. The only other point which should perhaps be mentioned is that the PIC16F88 micro (IC3) operates here from its internal RC clock, at a frequency very close to 8MHz. A clock signal of one quarter this frequency (ie, 2MHz) is made available at pin 15 of IC3, and is brought out to test point TP2, to allow you to check that IC3 is operating correctly.

Construction

Now that we have the design and operation under our belts, we're ready to move onto the construction.

Unfortunately, though, space has beaten us this month, so the complete constructional details, including the mounting of the project within the special case, will be presented next month.

In the meantime, the parts list is shown opposite, so you can start collecting the bits required. Firmware for the PIC micro will also be on the *EPE* website (**www.epemag.com**) next month.

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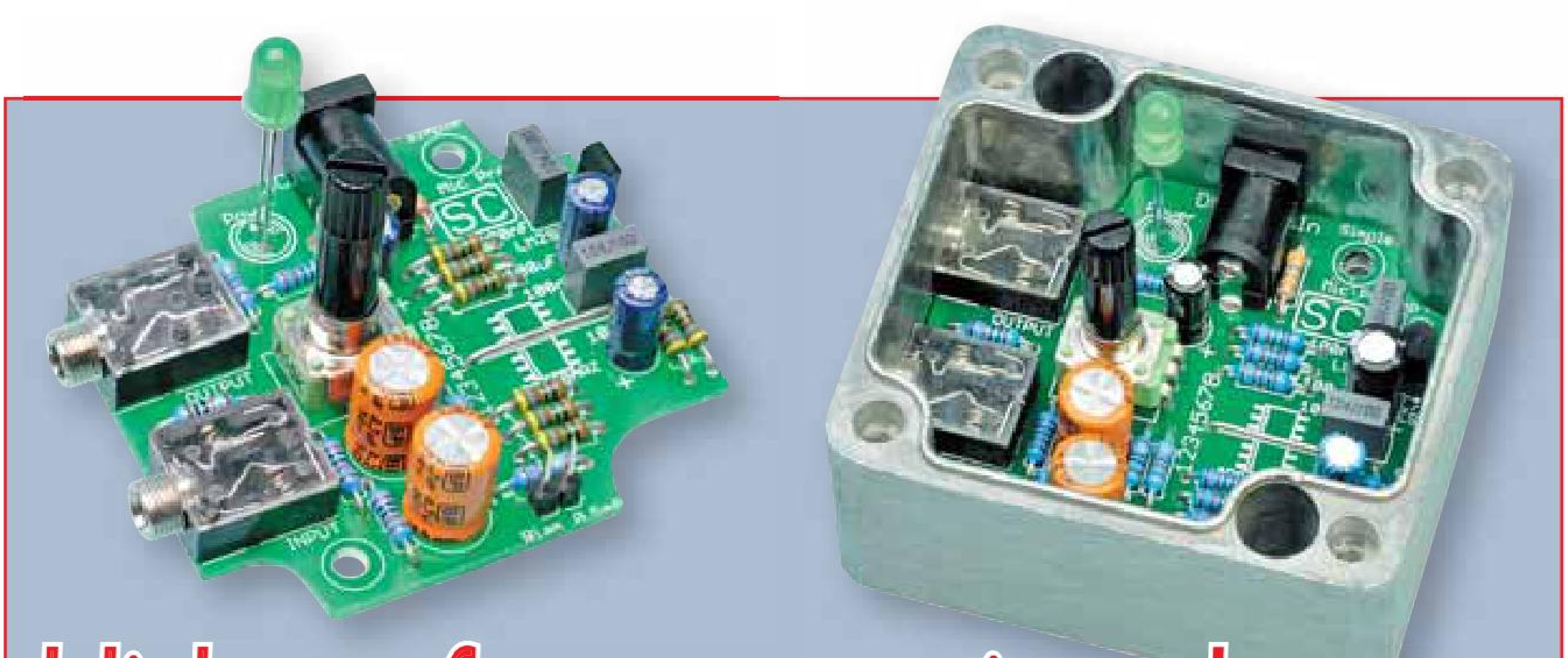


High-performance microphone preamplifier

Some recording devices, especially computer sound cards, have poor sound quality or insufficient gain when used with certain microphones. This tiny module provides a line level output from an unbalanced or balanced microphone and has very low noise and distortion. It runs off 5V to 20V DC, consuming just 6mA.

By NICHOLAS VINEN

THE reason that a microphone preamplifier is necessary is that most microphones, especially unpowered types, have a low output signal level. A typical microphone will deliver 10mV to 200mV RMS at maximum volume. Audio 'line level' is around 775mV RMS (0dBu) or higher, but a great deal of audio equipment can actually handle 1V RMS or more. Higher signal levels usually mean more dynamic range.

So, to interface a microphone to a mixer, computer sound card or amplifier, we need to insert a preamplifier inbetween to boost the signal level. Otherwise, it may be impossible to get enough volume.

Some such devices contain internal amplifiers, but they don't always perform well. Their internal microphone preamplifiers can be noisy and may not provide enough gain for some microphones (ie, those with very low output levels). Many, if not most, computer sound cards do not use high-quality analogue components.

Adding a microphone preamplifier does not guarantee good results, as the line level circuit can still introduce noise and distortion, but it certainly improves your chances of getting acceptable sound quality. On the other hand, a preamplifier is a necessity for connecting a microphone to any gear which only has line level inputs.

Performance

As can be seen from the specification panel and graphs, this preamplifier has very good performance despite its low supply requirements. Signals below 50mV RMS will result in worse performance, while higher level signals will provide better performance. For a 25mV RMS input, the signal-to-noise ratio will be reduced by 6dB, for 12.5mV by 12dB and so on. With a 100mV RMS input, the S/N ratio goes up to 94dB and THD+N improves to below 0.002%.

The performance doesn't vary with signal frequency. The frequency response is very flat, with –3dB points at around 1Hz and 1MHz (see Fig.1). The total harmonic distortion plus noise (THD+N) level is the same across the audible band (see Fig.2) and at typical microphone levels consists mostly of noise.

Under our test conditions with 50mV RMS input and 775mV RMS output, harmonic distortion accounts for just 12% of the total distortion measurement and is primarily second harmonic.

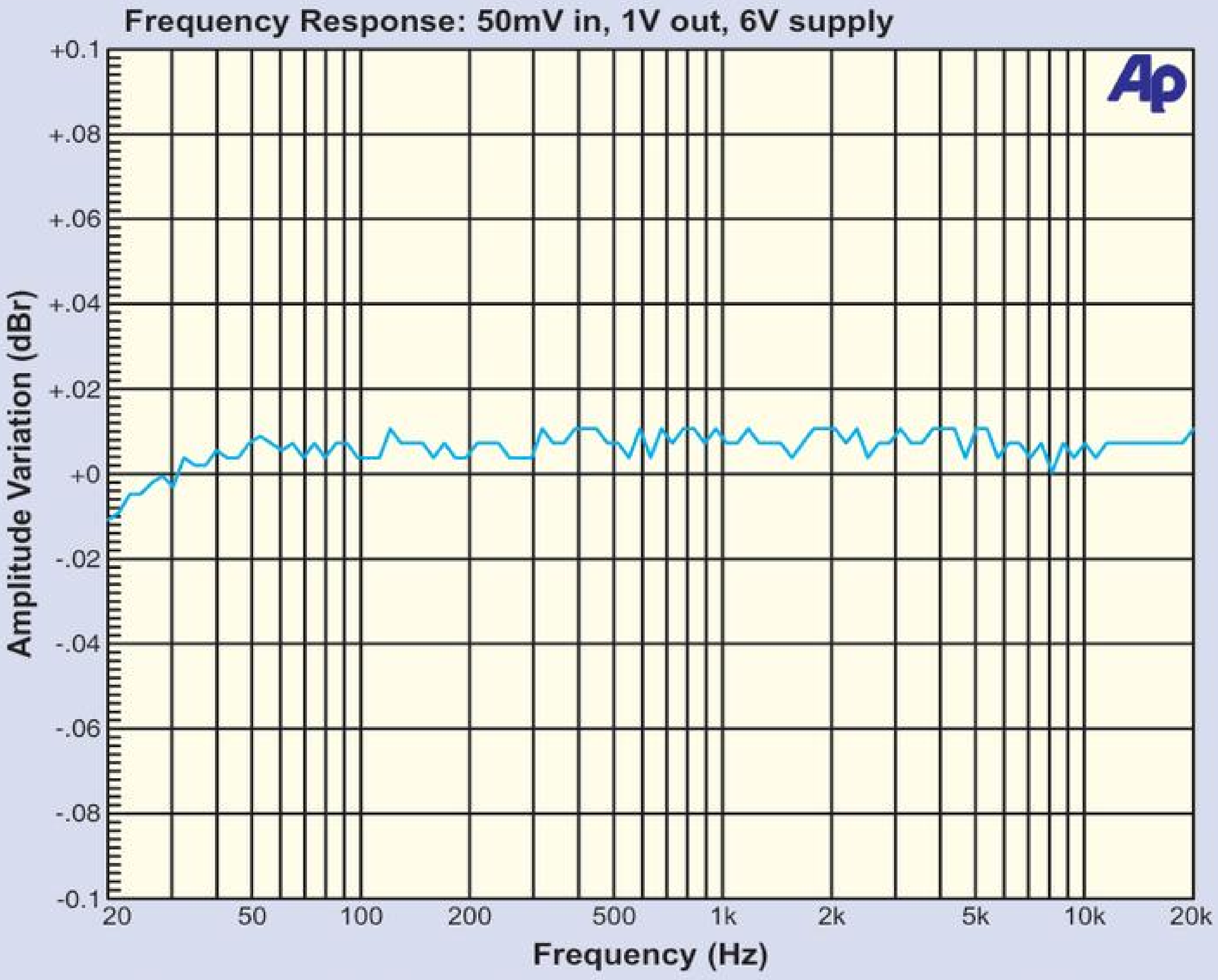


Fig.1: this graph plots the frequency response of the Mini Microphone Preamplifier. Note that the vertical scale is greatly magnified, as the frequency variation is within just ±0.01dB. This figure is at the limit of our Audio Precision System One test gear's resolution – the response is about as flat as it gets.

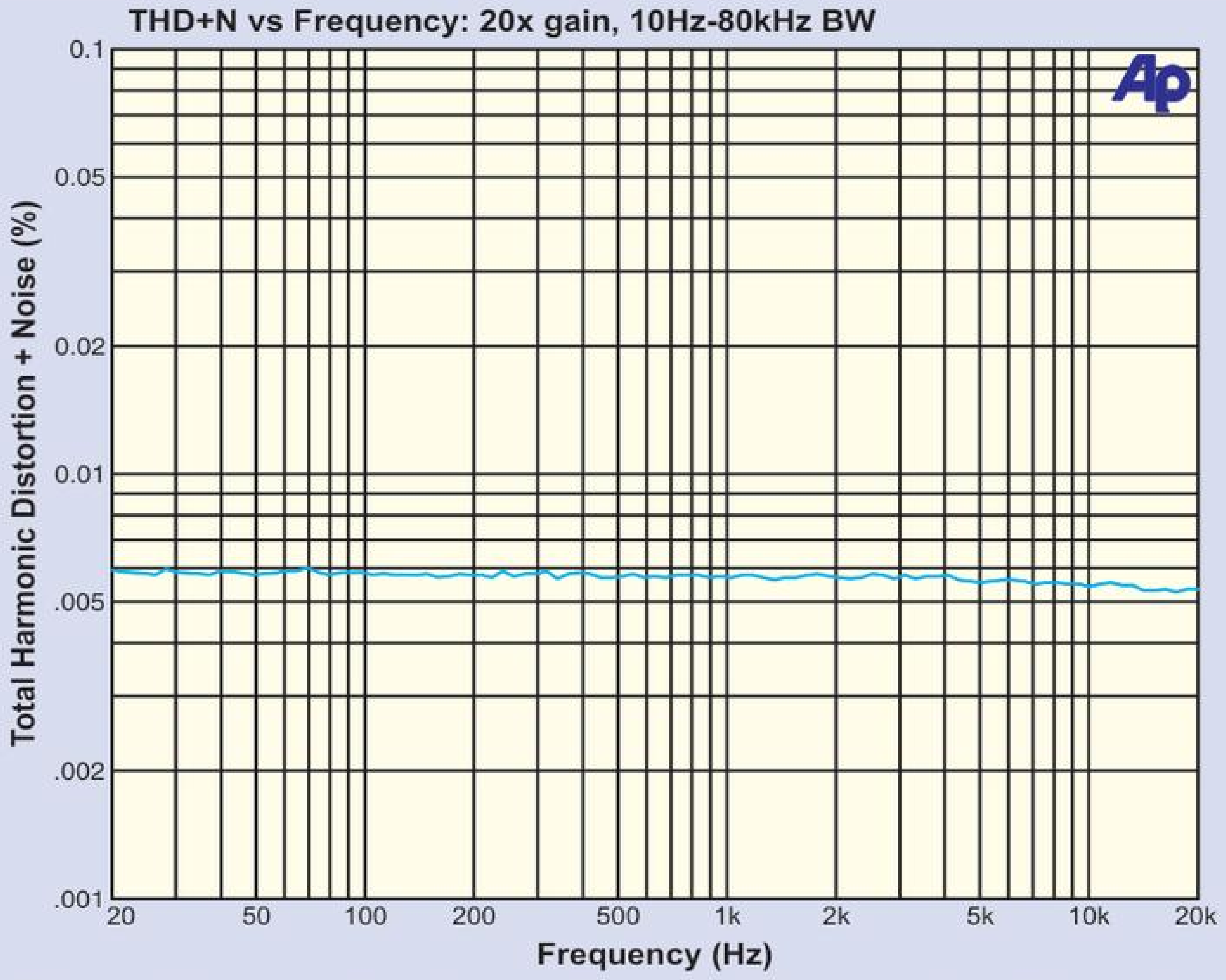


Fig.2: this graph shows the total harmonic distortion (THD) with respect to frequency. Distortion levels are higher than quoted because this is measured over a wider bandwidth (10Hz to 80kHz), so more noise is registered. The slight drop at high frequencies is due to the 80kHz cut-off. Again, this is essentially a flat measurement.

Such a wide frequency response is not necessary, but is the result of making this project as small and simple as possible. There is no low-pass filter, except for the internal compensation of the op amps. We are assuming that most devices which accept line level signals will have their own bandpass filters to remove frequencies outside the audio spectrum.

CMRR

The common-mode rejection ratio (CMRR) is a measure of how well a device with a balanced or differential input is able to reject a signal that is common to both inputs. In other words, if the same amount of 50/100Hz hum is coupled into both signal conductors in the cable, this is the amount by which that hum is attenuated.

For our first prototype, we used standard one percent resistors throughout, and measured a CMRR of –55dB. Our second prototype, used more expensive 0.1% resistors in the differential amplifier, which improved the CMRR to –88dB. In practice, –55dB is perfectly adequate unless you have a very long microphone cable run.

To get the best performance, either the power supply ground or signal ground should to be connected to earth. This reduces the possibility of mains 50/100Hz hum entering the circuit. However, you must avoid earthing *both* so that an earth loop cannot be created.

In other words, earth the supply ground, but only if neither the input nor output signal grounds are already earthed. The diecast aluminium box

Main features

- Unbalanced or balanced mono input (3.5mm mono/stereo socket)
- Unbalanced mono output (3.5mm mono socket)
- Very low distortion and noise
- Small and easy to build
- Runs off a 5V to 20V DC plugpack or battery
- Adjustable gain over a wide range
- Line level output to at least 1.5V RMS
- Provision for electret microphone bias (approx. 390µA)

5-20V DC
Power
Output
Gain
Input
Mini Mic Preamplifier

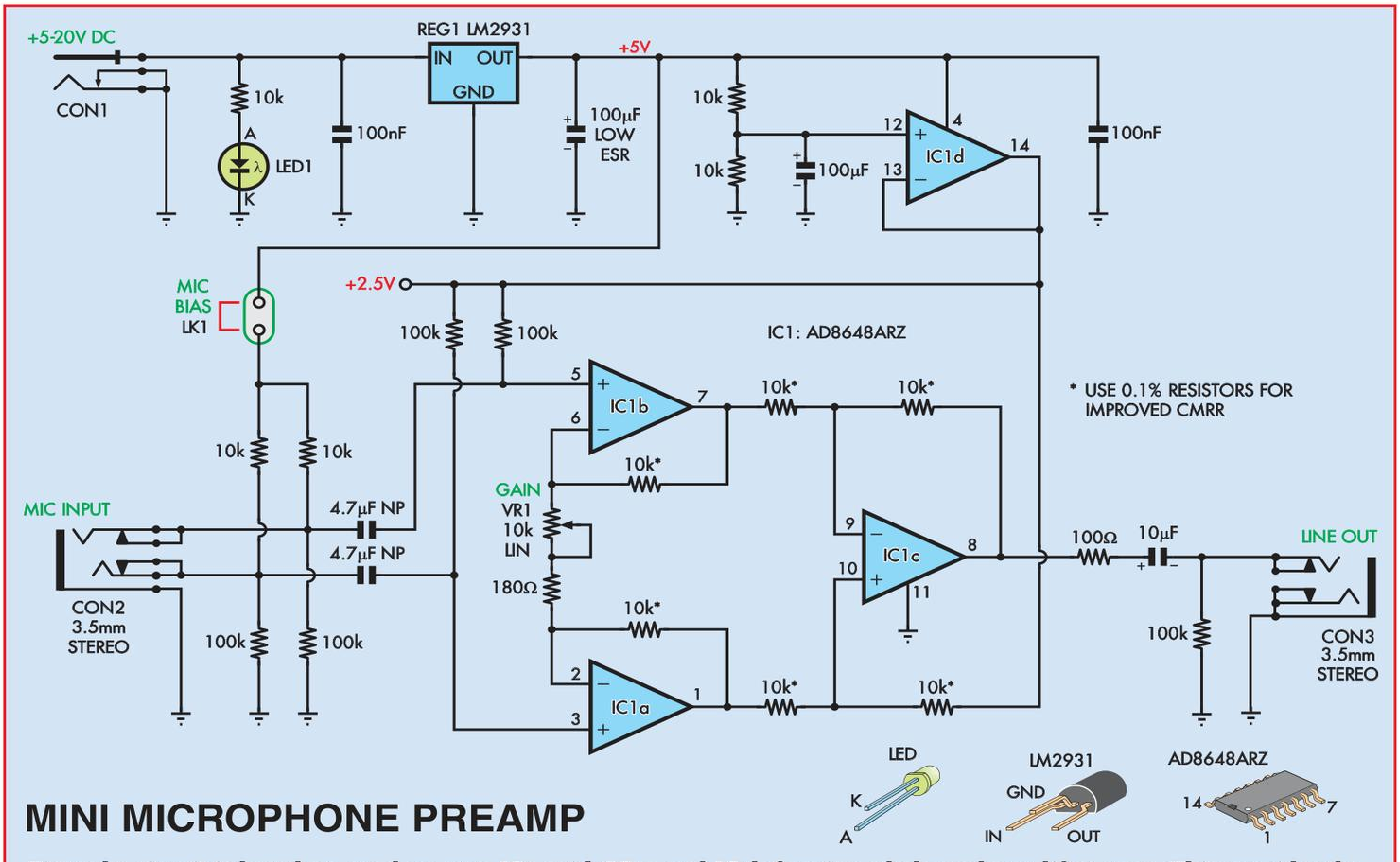

+5-20V DC
CON1
REG1 LM2931
IN
OUT
GND
+5V
10k
A
LED1
K
100nF
100µF LOW ESR
10k
10k
100µF
12
13
4
14
IC1d
100nF
MIC BIAS
LK1
+2.5V
100k
100k
IC1: AD8648ARZ
5
6
IC1b
7
10k*
10k*
* USE 0.1% RESISTORS FOR IMPROVED CMRR
10k
10k
10k*
GAIN
VR1
10k
LIN
MIC INPUT
4.7µF NP
4.7µF NP
180Ω
9
10
IC1c
8
11
100Ω
10µF
LINE OUT
CON2
3.5mm
STEREO
100k
100k
10k*
2
3
IC1a
1
10k*
10k*
100k
CON3
3.5mm
STEREO
LED
K
A
LM2931
GND
IN
OUT
AD8648ARZ
14
7
1
MINI MICROPHONE PREAMP

Fig.3: the circuit is based on quad op amp IC1, with IC1a and IC1b forming a balanced amplifier stage. This provides the gain and drives differential amplifier stage IC1c, which converts from a balanced to an unbalanced output signal. Regulator REG1 provides a +5V supply rail to power the circuit, while IC1d and the 10kΩ divider resistors on its pin 12 input provide a +2.5V half-supply rail to bias IC1a-IC1c.

is connected to ground (and therefore earth) to improve its magnetic shielding properties.

It is also very important to use shielded cables. Most of the distortion we encountered while testing the preamplifier's unbalanced performance was in the form of hum entering via the input lead. This changed depending on how the lead was routed.

We tested both the AD8648ARZ and AD8694ARZ quad op amps and found the overall performance to be the same. Use whichever one is easiest or cheapest to obtain.

Balanced input

While this circuit was designed with cheap, unbalanced microphones in mind, it is able to handle balanced signals too. These have the advantage of good noise cancellation, eliminating hum, especially with long cable runs.

However, because the unit is so small we cannot fit the standard XLR type connectors. Instead, we are using the tip and ring of a 3.5mm stereo connector for the positive and negative balanced signals respectively.

If you intend using unbalanced microphones, we assume that they will be fitted with a mono 3.5mm jack plug. Inserting this into the 3.5mm stereo socket will ground one side of the balanced input, to give unbalanced operation.

To test its balanced capabilities, we used an XLR to 6.5mm Tip-Ring-Sleeve (TRS) cable with a 6.5mm-to-3.5mm stereo adaptor on the end. Both XLR and 6.5mm TRS connectors are used for balanced audio connections on professional gear, so getting such cables is easy enough. Unfortunately, professional gear does not come cheap. The cable probably cost more than the preamplifier!

Using a balanced input cable isn't strictly necessary, but our tests showed that it is by far the best way to eliminate mains hum from the equation. With an unbalanced input cable, we could only eliminate the hum by watching the signal on the oscilloscope and moving the cable around until the 50Hz component disappeared.

In practice, hum will always be a problem when using unbalanced microphones. Substituting a balanced cable (and signal) completely eliminates it, regardless of the cable routing.

Note that the metal enclosure is less critical if you are using a balanced microphone. This is because the low-level signals on the PC board are all differential – by the time the signal is converted to unbalanced, it has already been amplified, so mains interference is less of a problem. With a balanced signal, even if the PC board is mounted in a plastic enclosure, performance should be good. Tests at our office show no loss in performance running the bare board with a balanced input signal.

Op amps

The AD8646/7/8 and AD8691/2/4 op amps we have used in this project provide excellent performance from a low supply voltage. They both feature a low input noise of 8nV/√Hz – the same as an OPA2132/4. This is not quite as good as an NE5532, NE5534 or LM4562, but it is impressive nonetheless, especially as they operate from such low supply voltages.

The AD8648 has a gain bandwidth (GBW) of 24MHz, while the AD8694 has a GBW of 10MHz. The AD8694 features a THD+N figure of 0.0006% and a low input offset voltage of 400µV (with low drift), while the AD8648 can deliver 120mA from its outputs and handles 600Ω loads gracefully. Both have very low input bias current (<1pA) and low quiescent supply current (<2mA per amplifier).

Both op amp series are only available in surface-mount packages – small outline integrated circuit (SOIC) or the finer-pitched thin shrink small outline package (TSSOP) or mini small outline package (MSOP). That is the trend these days, and many modern, high-performance ICs are no longer available in through-hole packages. Having said that, these SMD packages are reasonably easy to solder.

These op amps are ideal for high-quality audio processing in battery-operated equipment. The AD8646/7/8 (single/dual/quad version) can even do a decent job of driving a headphone load. In this application, we have chosen them primarily for their low noise and distortion, as well as their reasonable price.

Specifications

Supply voltage: 5V to 20V DC (operates at 2.8V to 5V with reduced performance)

Supply current: typically below 6mA

Voltage gain: ×3 to ×111

Input sensitivity (line level output): 14mV RMS

Input sensitivity (1V RMS output): 18mV RMS

Input impedance: 50kΩ (8.3kΩ with bias enabled)

THD+N ratio: 0.0035%

THD+N ratio (10mV RMS in): 0.014%

Signal-to-noise ratio: –90dB (–93dB A-weighted)

CMRR* (1% resistors): –55dB

CMRR* (0.1% resistors): –88dB

Frequency response: 20Hz to 20kHz ±0.01dB

Signal handling: >1.5V RMS output

Signal handling (3.0V supply): >1.0V RMS output

Note 1: CMRR = Common-mode rejection ratio
Note 2: all specifications relative to 50mV RMS input, 775mV RMS output, 20Hz to 22kHz bandwidth and a 6V supply, unless otherwise stated.

Circuit description

Refer now to Fig.3 for the full circuit diagram of the *Mini Microphone Preamp*. As shown, power is supplied via PC-mount DC socket CON1, with green LED1 indicating operation. The 10kΩ current-limiting resistor is a much higher value than usual, and as a result, the LED glows dimly. This is to conserve power if the preamplifier is being run from a battery. If you don't plan to use a battery or don't mind a few milliamps of extra current drain, then you can change the 10kΩ resistor to 1kΩ so that the LED is brighter.

Since the LED runs off the unregulated supply, its brightness will depend on the supply voltage. This means that it can also be used as a crude battery level meter.

Regulator REG1 is an LM2931 low-dropout (LDO) type, so its output voltage is stable with an input as low as 5.1V. Its quiescent current is typically below 1mA, again contributing to good battery life.

Below 5.1V, REG1 ceases regulating, but the circuit can still run, as long as the input supply is at least 2.8V. However, the maximum output signal level is lower with a supply below 5.1V. With a 2.8V supply, the maximum output level is 950mV RMS, which is still above line level.

There is no supply polarity protection diode, because REG1 can withstand negative voltages and its input filter capacitor is a non-polarised type. The 100µF capacitor at its output filters the regulated voltage and is necessary for stability. Because REG1 is an LDO type, the output capacitor must be at least 100µF, and its equivalent series resistance (ESR) has to be between 0.03Ω and 1Ω. That is why we have specified a low-ESR type (listed as 0.22Ω).

In reality, many other 100µF capacitors are probably suitable, but they would need to be tested using an ESR meter before installation to ensure that they are within the acceptable range.

The two 10kΩ resistors between REG1's output and ground form a voltage divider, the junction of which is at half the supply voltage (normally +2.5V). This is necessary because the op amps use ground as their negative rail. Their input and output AC signals must be biased to this virtual ground potential so that the signals always stay between the two supply rails (5V and 0V).

The second 100µF capacitor filters this virtual ground. This is important, as otherwise supply noise could couple into it and noise on the virtual ground will couple directly into the signal path.

The half-supply voltage is fed into op amp IC1d, which is configured as a voltage follower. Its output is the same voltage as its input, but has a much lower impedance, so any current fed into the virtual ground has no effect on its level.

The two input signals at the 3.5mm socket CON2 (one of which is grounded with an unbalanced microphone) are DC-biased with 100kΩ resistors in case the signal source is floating. If a jumper link is placed across LK1, these signal lines are pulled up via 10kΩ resistors to provide a 390µA bias current for an electret microphone – see panel. Regardless of the DC biasing, the signals pass through the two 4.7µF non-polar AC-coupling capacitors.

Next, the signals are biased to a DC level of 2.5V by two 100kΩ resistors and then enter the differential amplifier. Op amps IC1a, IC1b and IC1c are

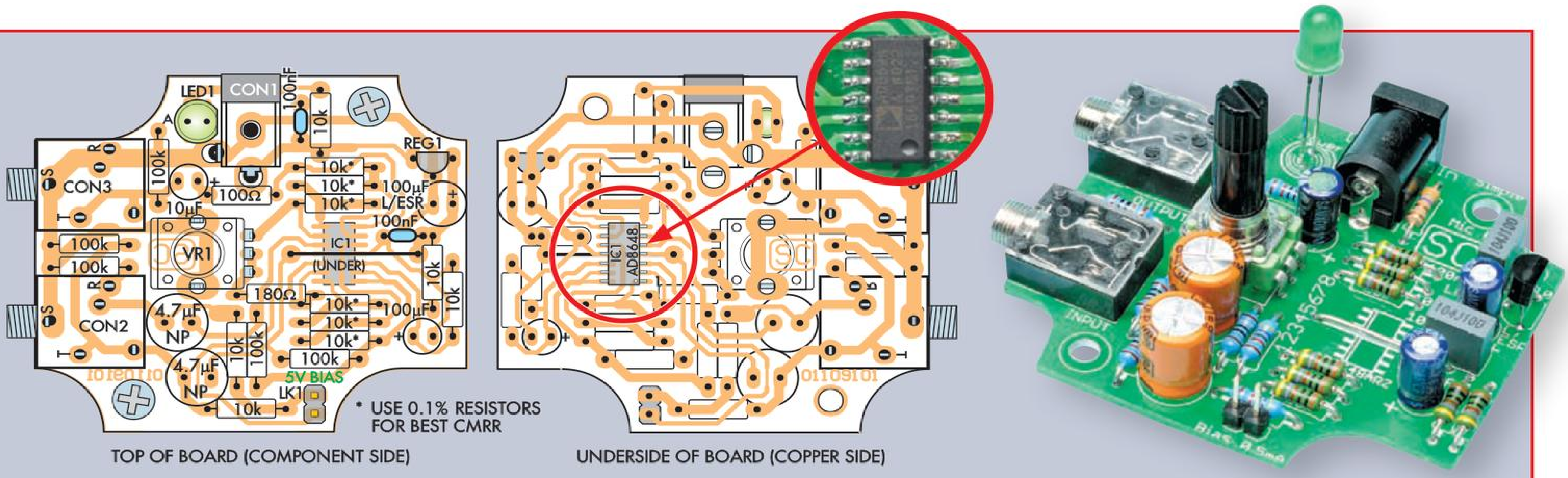


Fig.4: here's how to install the parts on the PC board. IC1 should be installed first – it goes on the copper side of the board and must be orientated with pin 1 at bottom right (see photo). The jumper is installed for LK1 only if you intend using an electret microphone – see panel. Note that the prototype board shown in the photo differs slightly from the final version.

configured in the classic instrumentation amplifier layout. IC1a and IC1b have a high impedance input and provide the gain which is varied by potentiometer VR1.

Gain control VR1 and its series 180Ω resistor form a voltage divider, along with the 10kΩ resistors to the outputs of IC1a (pin 1) and IC1b (pin 7). As a result, when VR1 is turned clockwise and its resistance decreases, the gain of both IC1a and IC1b increases.

Note that, in each case, the 'bottom end' of the divider network is not connected to ground, but rather to the output of the opposite op amp. This provides much better common-mode rejection. That's because the gain of each op amp can vary due to resistor tolerances, but since the gain is differential, it does not matter.

The buffered and amplified signals are now passed to IC1c, which is connected as a differential amplifier. It converts the balanced signals from IC1a and IC1b to an unbalanced signal. The resulting waveform is then AC-coupled via a 10µF electrolytic capacitor to CON3, the 3.5mm stereo output socket.

Note, however, CON3's ring terminal is grounded, which means you *must* use a mono jack plug. The associated 100kΩ resistor references the output signal to ground, while the 100Ω series resistor isolates the output from capacitive loads to ensure stability.

Construction

All the parts are mounted on a PC board coded 859 and measures 56mm × 49.5mm. This board is available from the *EPE PCB Service*. The board has corner cutouts to clear the corner pillars in the specified diecast metal case.

Fig.4 shows the component layout. Begin construction by checking the copper side of the board for any defects (cracks, short circuits). Check also that it is the correct shape to fit in the box. If necessary, make the corner cutouts using a small hacksaw and file.

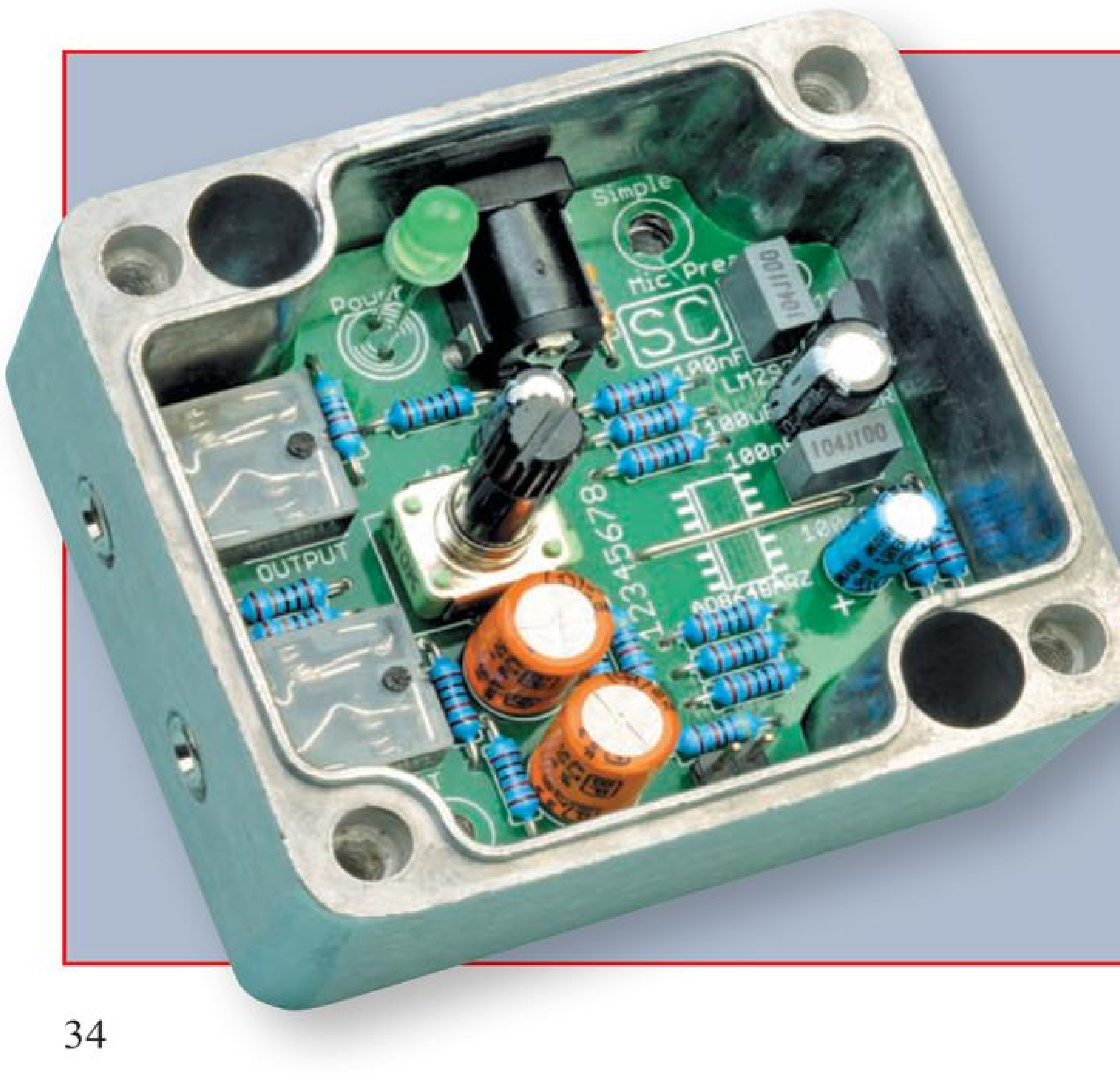
Make sure that the board goes all the way down into the box. The inside of the specified box tapers slightly, and it may be necessary to file the edges of the board so that it fits.

The next step is to solder the surface-mount IC (IC1) into place. This is a 14-pin SOIC package and is fairly easy to solder provided due care is taken. You will need a soldering iron with a fine tip and a good light (preferably a magnifying lamp).

First, place the PC board copper side up and with the SMD pads positioned as shown in Fig.4. That done, apply a small amount of solder to one of the pads – eg, the upper-right pad if you are right-handed or the upper-left pad if you are left-handed.

Now place the IC alongside the pads, with the bevelled edge on the right-hand side and the pin 1 dot at the bottom-right. Check that it is correctly oriented, then melt the solder on the pad (taking care not to spread it to adjacent pads) and gently slide the IC into place. Do not apply heat for more than a few seconds.

Next, press down gently on the IC and re-heat the pad, allowing the solder to melt. This ensures that the IC is sitting flat on the board. Now check that the pins are all aligned with their pads. If not, re-heat the soldered pad



This view shows the completed PC board mounted inside its diecast metal case. This case makes for a rugged assembly and provides the necessary shielding.

Biasing electret microphones

Electret microphones have an internal field effect transistor (FET) which amplifies the very low signal level that they generate. This FET requires a source of current to operate. Some such microphones contain an internal battery, in which case they can be treated like any other microphone. However, others require power to be sent along the input cable, in a similar manner to 'phantom power'.

If you have an unbalanced electret microphone which requires external power, this unit can deliver it. A jumper shunt placed on the 2-pin header (LK1) enables the bias current. Assuming the microphone's bias voltage is 1V, it will receive 390μA. Some electrets require more current – up to 800μA – but others can be damaged if more than 400μA is supplied.

If your microphone needs more current then you can change the two 10kΩ resistors near the non-polarised capacitors to 5.1kΩ. In this case, the bias current will increase to 775μA with a bias voltage of 1V.

This unit will also provide power for balanced condenser microphones, using the same 2-pin header.

Parts List

1 PC board, code 859, available from the *EPE PCB Service*, size 56mm × 49.5mm
1 diecast sealed aluminium box, size 64mm × 58mm × 35mm (Jaycar HB5030)
1 2.5mm PC-mount DC power socket (Jaycar PS0520)
2 3.5mm PC-mount stereo switched socket (Jaycar PS0133)
1 2-pin header (2.54mm pitch)
1 10kΩ linear 9mm vertical PC-mount potentiometer
1 jumper/shorting block
1 50mm length of tinned copper wire or 0Ω resistor

Semiconductors
1 AD8648ARZ or AD8694ARZ quad low noise rail-to-rail op amp (IC1) (Farnell or RS)
1 LM2931Z-5.0 or LM2931AZ-5.0 low dropout 5V regulator (REG1)
1 5mm green LED (LED1)

Capacitors
1 100μF 16V low-ESR electrolytic (Jaycar RE6310)
1 100μF 16V electrolytic
1 10μF electrolytic
2 4.7μF non-polar electrolytic
2 100nF multilayer ceramic

Resistors (0.25W, 1%)
5 100kΩ
11 10kΩ
1 180Ω
1 100Ω
Optional: use 6 x 10kΩ 0.1% for improved CMRR – see Fig.4

and slide the IC until all the pins are lined up, then apply solder to the diagonally opposite pin.

It's now simply a matter of flowing a small amount of solder onto the remaining pads. Ensure that it adheres to both the pad and the pin in each case. Generally, this is achieved by ensuring that the soldering iron remains in contact with the pad for about one second after the solder is applied. If you accidentally join any of the adjacent pads or pins together, remove the excess solder using solder wick.

Finally, apply a small amount of additional solder to the first two pads you soldered to hold the IC in place, to ensure the solder has flowed correctly. Once it's finished, use a magnifying glass to check that all the pins have been correctly soldered, and that there are no solder 'bridges'.

Topside assembly

With IC1 secured, the parts can now be installed on the top of the board. Begin by fitting the single wire link using 0.71mm tinned copper wire or a 0Ω resistor, then install the resistors. You should check the value of each one using a DMM before installing it.

If you are using 0.1% 10kΩ resistors to get the improved CMRR figure, be sure to install them in the locations marked with black asterisks on Fig.4. The remaining 10kΩ resistors can be 1% types without affecting the performance.

Now mount the two 3.5mm stereo sockets. First, remove the nuts from both and discard them, then press the sockets down so that they sit flat on the PC board. Check that they are aligned with the edge of the board before soldering all the pins.

Follow these with the two multilayer ceramic capacitors. They are the same value and can go in either way.

The LM2931 regulator in the plastic TO-92 package can go in next. Use small pliers to bend its legs out by 45° and then back down parallel again so that they will fit through the holes in the PC board. Make sure its flat face is oriented as shown on the component layout (Fig.4).

The 2-pin header is next on the list, followed by the polarised electrolytic capacitors. **Check that the 100μF low ESR type goes in next to the regulator,** and that they are all oriented correctly. Don't get the 10μF and 100μF capacitors mixed up.

The two 4.7μF non-polarised electrolytics can be fitted either way around. Install these now, then fit the DC power socket. The latter should sit flush with the board and its pins soldered using generous amounts of solder.

Finally, install the 5mm green LED. This goes in with the bottom of its plastic body 19mm above the PC board and its flat edge towards CON1 – see Fig.4. A strip of cardboard cut to 19mm can be inserted between its pins when soldering it in to set the correct height.

Testing

It is a good idea to test the board before installing it in the box. Once it's installed, it can be difficult to remove.

The first step is to install the shorting jumper on the 2-pin header if your microphone requires a bias current (ie, if it is an electret – see panel). That done, apply power (a plugpack is the easiest) and check that the LED lights. If it doesn't, then either the supply polarity is reversed or you have a short circuit between two copper tracks.

Once it has power, turn the gain control all the way down and connect a signal source to the input socket. You can use a microphone or some other mono or balanced signal source. A stereo signal will not work very well however, as the two channels will be subtracted from each other by the differential amplifier.

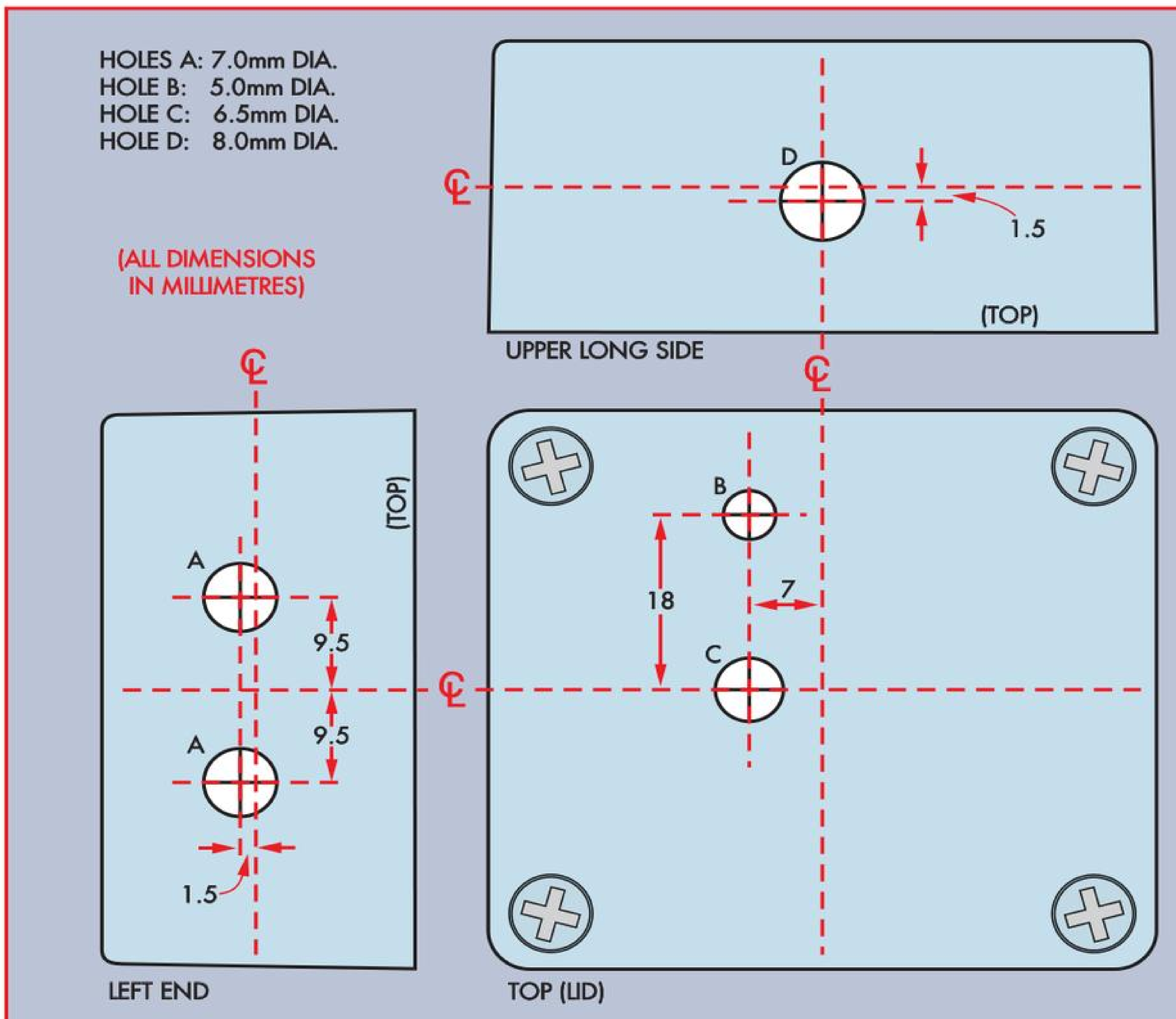


Fig.5: these are the drilling templates for the case. Use a small pilot drill to drill the centre of each hole initially, then carefully enlarge them to full size using a tapered reamer.

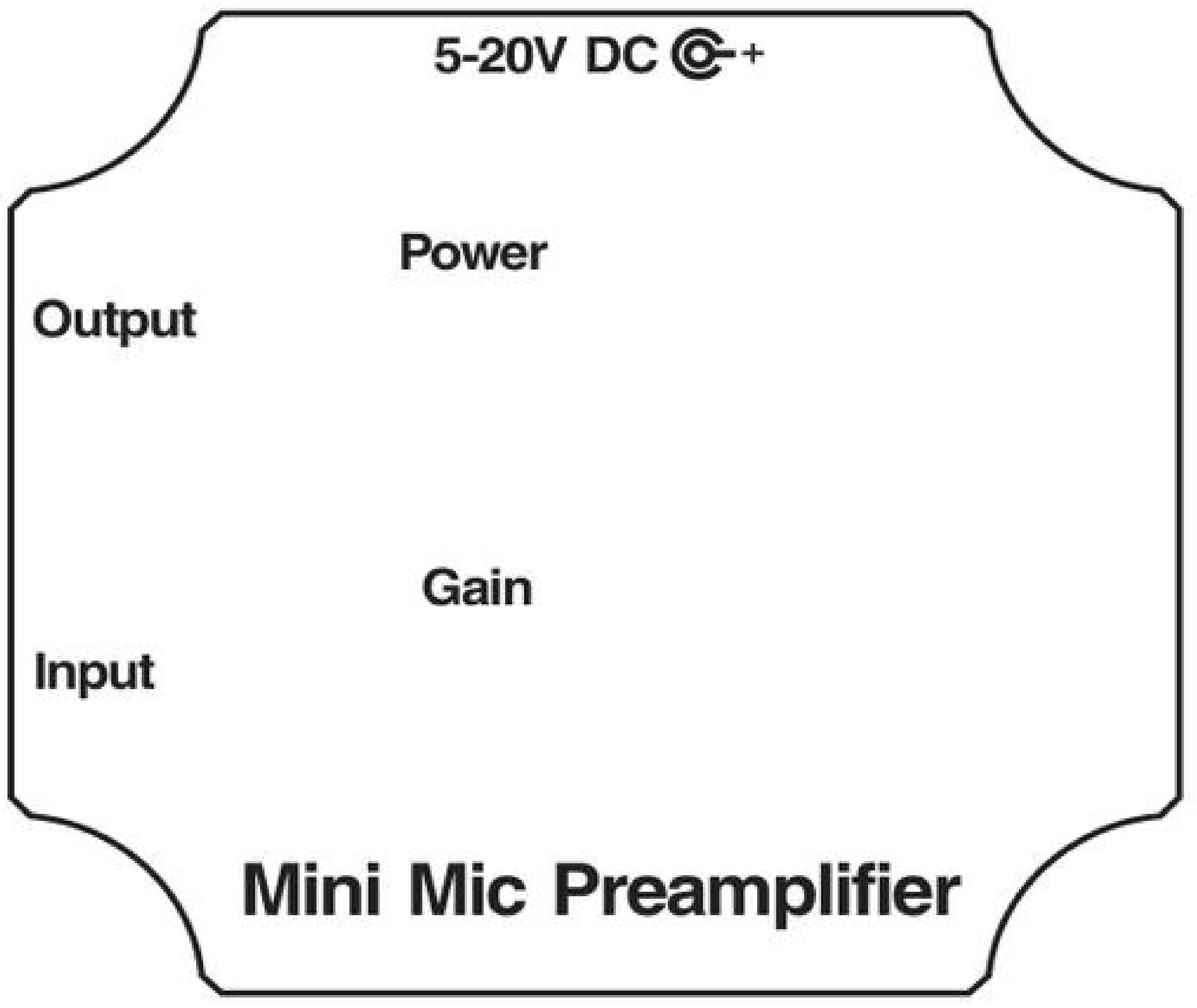


Fig.6: this front panel artwork can be photocopied and glued to the lid of the diecast box, or attached to the box using double-sided tape.

Next, connect the output socket to an amplifier or use some other method to monitor the output signal (eg, a scope). Now slowly increase the gain control on the preamplifier and check that the input signal is being correctly fed through to the amplifier. If you are using a microphone for this test, be careful to avoid feedback between the monitoring speakers and the microphone. If everything checks out, switch off and put the board to one side.

Final assembly

Assuming all is well, use the drilling templates shown in Fig.5 to make the five holes in the diecast box. It's best to initially drill the centre of each hole with a small-diameter bit (eg, 3mm) and then carefully enlarge them to full size using a tapered reamer (this will ensure that they are accurately placed). Deburr each hole using an oversize drill.

Once the holes have been made, insert the board with the two 3.5mm sockets angled downwards. Push these into the appropriate holes and then lever the board down. The DC socket should clear the edge of the box, allowing you to lay the board flat on the internal 'shelves'.

If it won't go in, you may need to file the board edges where it is catching on the box, or slightly enlarge the holes for the 3.5mm input and output sockets.

Grounded

Once the board is in, secure it in position with the two screws provided with the box. Now, using a multimeter set on continuity mode, check that the board ground is electrically connected to the box. You can use the exposed metal tab on the side of the DC socket as a ground test point.

It is also a good idea to ensure that there is no short circuit between the exposed wire link on the top side of the PC board and the box, or between the exposed tab on the rear of the DC socket and the box. If there is, your power source will be shorted out when it is plugged in.

If you do get a short, remove the PC board and check for any leads or other metal pieces sticking out on the underside which may be contacting the box.

Final check

Assuming there are no short circuits, plug your power source back in and check that the preamplifier still works. If not, there may be a short circuit from one of the signal paths to the box for the same reason stated above. The board has been designed so that the component pads clear the box edges and shelves (except for the ground track) but there may be some circumstances under which they can make contact.

All that remains now is to fit the front panel and attach the lid. You can photocopy the artwork shown in Fig.6. It can be protected using wide strips of clear tape (or laminated) and attached using a smear of silicone sealant.

The gain control shaft (VR1) and LED should project through the holes in the lid by a few millimetres – just enough to allow the gain control to be adjusted with your finger tips while making it difficult to accidentally alter it if it is bumped.

If you wish, you can press the provided neoprene seal into the recess underneath the lid just prior to fitting it. However, the holes drilled earlier mean that the box is no longer dustproof or waterproof. ***EPE***

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SP153	4 x 8mm Yellow Leds
SP154	15 x BC548B transistors
SP155	6 x 1000/16V radial elect. caps
SP160	10 x 2N3904 transistors
SP161	10 x 2N3906 transistors
SP164	2 x C106D thyristors
SP165	2 x LF351 Op-amps
SP166	20 x 1N4003 diodes
SP167	5 x BC107 transistors
SP168	5 x BC108 transistors
SP172	3 x Standard slide switches
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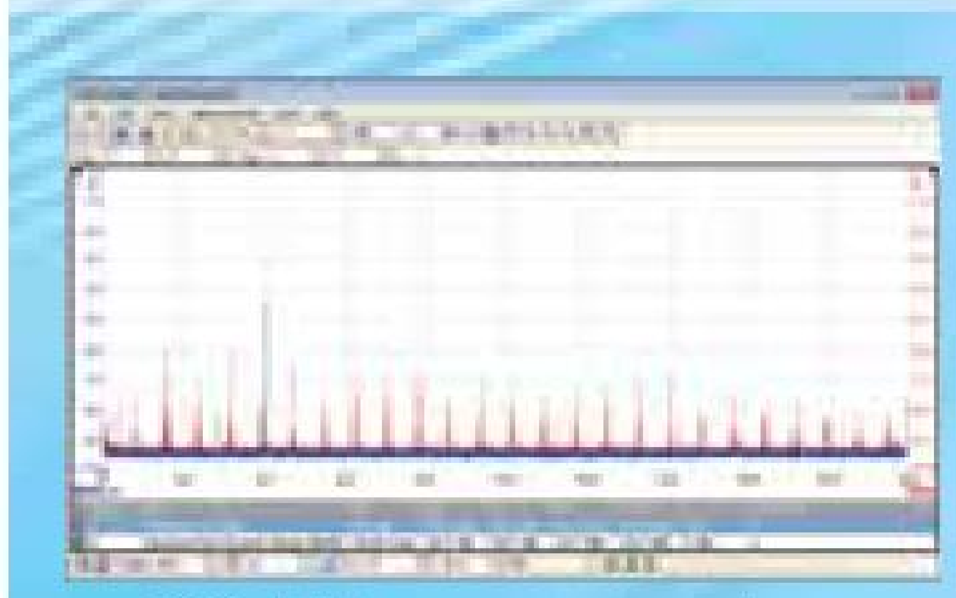

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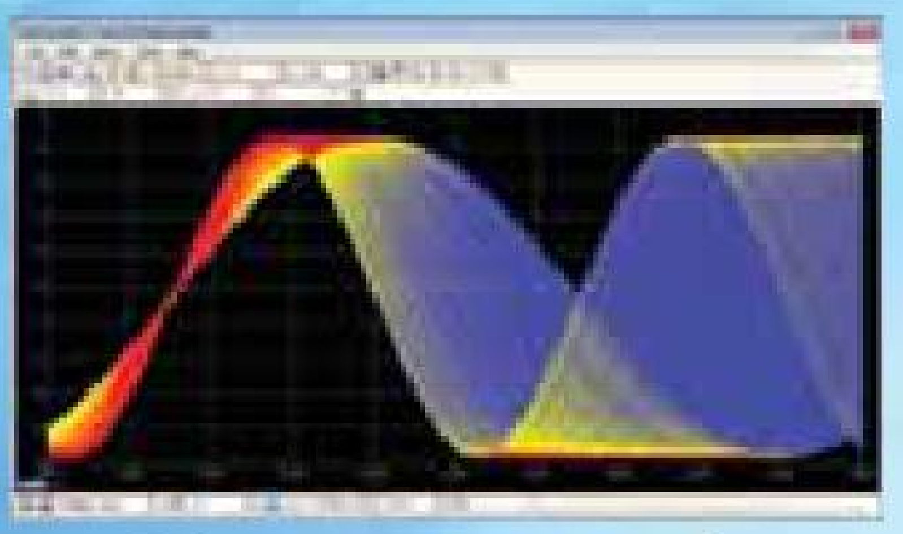

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Words by Leo Simpson
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HIGH-POWER REVERSIBLE DC MOTOR SPEED CONTROLLER

Here's a 12V to 32V 30A speed controller that's easy to build. It's available in two versions – reversible and non-reversible – and features soft start, relay switching of motor direction and PWM speed control.

THIS reversible *DC Motor Speed Controller* uses a pair of high-power MOSFETs, connected in parallel, to drive the motor and a unique relay changeover circuit to make it reversible. It can operate from 12V to 32V batteries, at currents up to 30A. Logic control of the relay changeover circuit means that it can only change direction when the motor is stopped.

The unit comes in two versions. The first is the basic speed control with two paralleled MOSFETs and a dual op amp to provide pulse-width modulation (PWM). The second version adds the relay changeover circuit and its logic control. If you don't need a reversing feature, you only need the basic version. Either way, speed control can be via an onboard trimpot, an external 5kΩ potentiometer, or a motorcycle throttle based on a Hall effect sensor – ideal for a wheelchair controller or an electric bike.

Circuit description

Refer now to the *DC Motor Speed Control* circuit (Fig.3), which shows both sections of the circuit. The left-hand side is the basic speed controller, while on the right-hand side are the relays and associated logic control.

First, let's focus on IC1 (the LM358 dual op amp) and the 5kΩ potentiometer. Op amp IC1a and its associated components comprise a triangle wave oscillator. Its frequency is around 300Hz, and its output amplitude is around 1V peak-to-peak. The mean DC level of this triangle waveform can be lifted up or down, dependent on the setting of the 5kΩ speed control potentiometer.

This output waveform is connected to the non-inverting input of IC1b, pin 5. IC1b is connected as a comparator and it compares the triangle waveform with the 3.5V fixed reference at its pin 6. When the speed control is advanced so that the peaks of the triangular waveform at pin 5 exceed the 3.5V

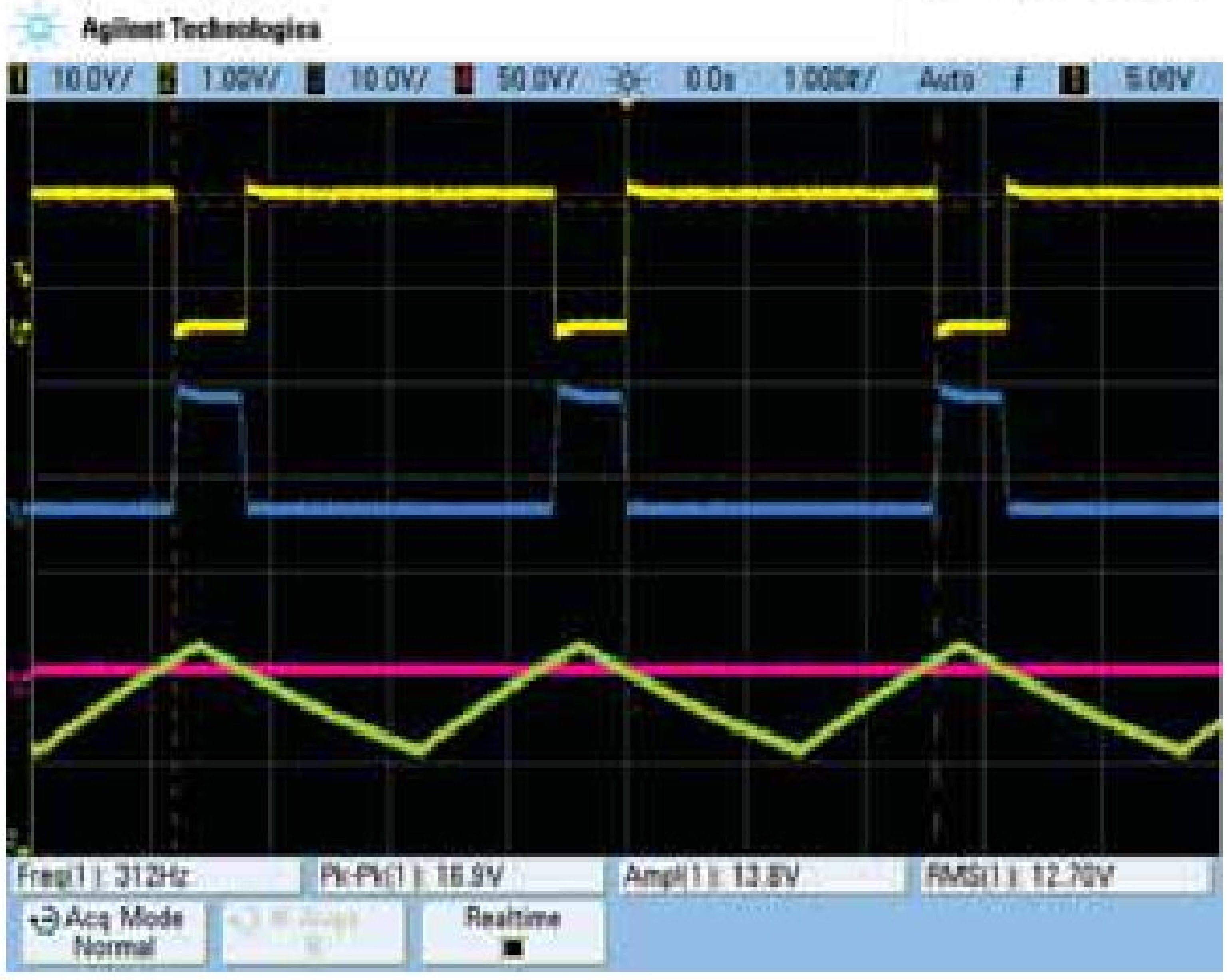


Fig.1: this scope grab illustrates the basic operation. The triangle wave (green) from the oscillator is compared to a 3.5V reference (pink trace), and when it exceeds this reference, a corresponding motor drive pulse (blue trace) is produced.

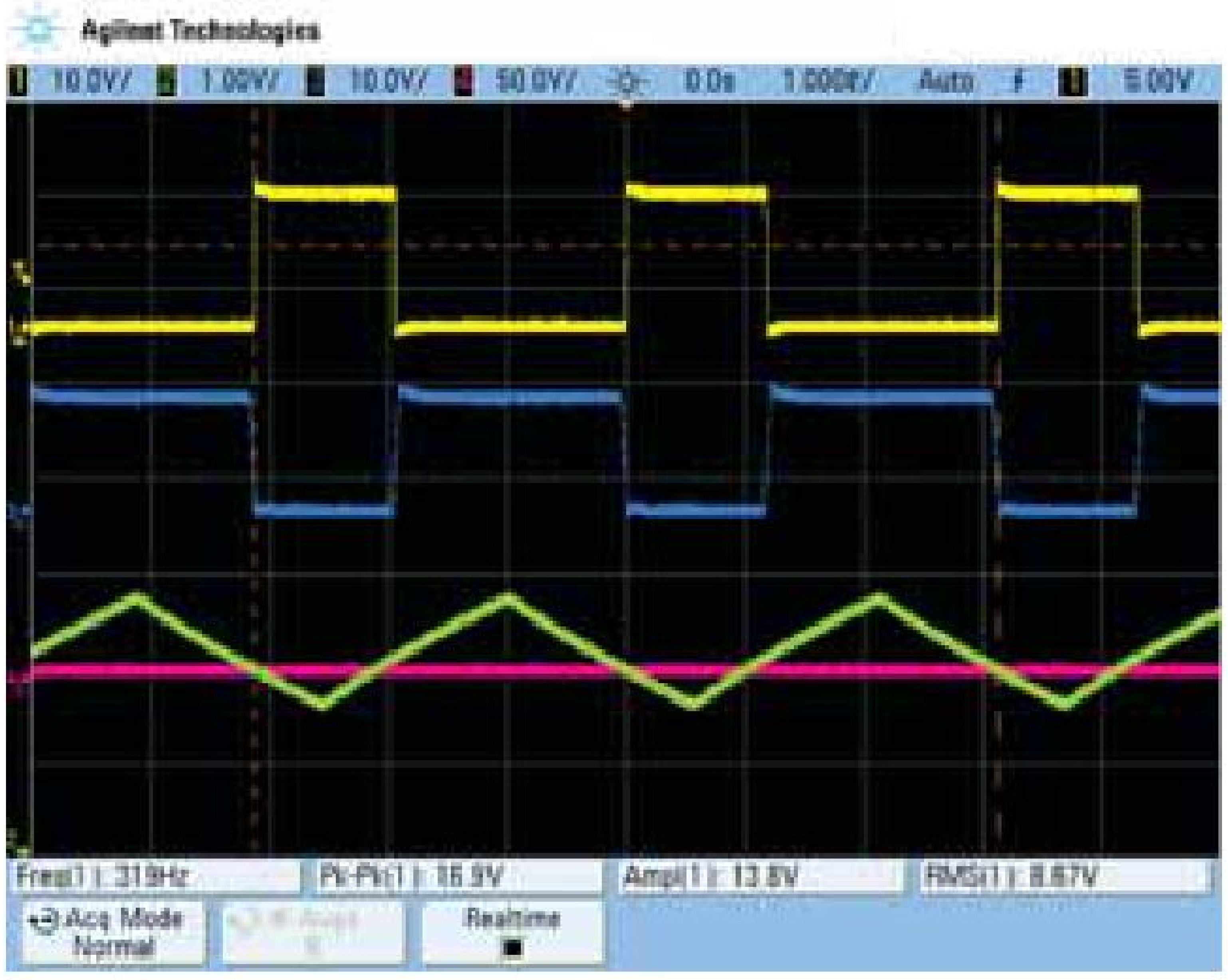


Fig.2: this scope screen grab shows the operation at higher throttle settings. The triangle waveform now exceeds the reference voltage for a greater proportion of the time and so the pulses fed to the motor are much wider.

reference voltage at pin 6, the output at pin 7 goes high and this turns on two power MOSFETs, Q6 and Q7.

This means that the MOSFETs are pulsed on whenever the triangle waveform peaks go above 3.5V. Advancing the speed control increases the duty cycle of the pulses.

Circuit operation

The circuit operation is demonstrated above in the two scope screen grabs of Fig.1 and Fig.2. In each case, the green trace shows the triangle waveform, while the pink trace shows the 3.5V reference, which is fixed. As you can see, each time a portion of the triangle waveform intersects the pink trace and is above it, there is a corresponding pulse to the MOSFET gates, as shown by the blue trace.

The voltage across the motor, between the positive supply line and the MOSFET drains (D), is shown in the yellow trace.

Fig.1 shows the operation at a very low throttle setting, and so the pulses fed to the motor are very narrow and its speed will be low. By contrast, Fig.2 shows the operation at higher throttle settings. As can be seen, the corresponding pulses fed to the motor are much wider.

When the throttle control is fully advanced, this results in the triangle waveform being wholly above 3.5V. This means that pin 7 of IC1 remains high permanently and so MOSFETs Q6 and Q7 are turned on continuously.

Soft start

When power is first applied to the controller circuit, the 100µF capacitor on pin 6 of IC1b is discharged, which means that pin 6 will be high at about +7V. The capacitor then begins to charge via the 39kΩ resistors on pin 6, thus pulling the voltage at pin 6 down to 3.5V. Therefore, at the instant when the power is applied, the motor cannot run, even if the throttle is fully advanced.

This gives the circuit a 'soft start' feature, and the motor cannot start with a lurch at initial power-up.

Two regulators

There are two transistor regulator circuits in the controller. The first regulator, comprising transistors Q2 and Q3 and red LED1, provides the +7V rail. It works like this: LED1 provides a 1.8V reference at the base of Q3, and the resulting 1.1V at Q3's emitter causes 2.34mA to flow in its 470Ω emitter resistor and through the 3.3kΩ resistor at its collector. This provides +7.7V at Q2's base and so +7V appears at Q2's emitter. This sets the voltage conditions for the throttle and the triangle wave generator based on IC1a.

The second regulator is based on Zener diode ZD1 and transistor Q5. Zener ZD1 provides a 15V reference and is bypassed by a 47nF capacitor to the base (B) of Q5, which operates as an emitter follower. Interestingly, for battery voltages of less than about 16V, ZD1 will not be biased on (ie, no Zener current will flow) and therefore Q5 will act as a simple capacitance multiplier filter.

It provides the supply rail to IC1 and thereby ensures that the gates of the MOSFETs are driven with more than 10V, provided the battery voltage is at least 12V. This is desirable to ensure that the MOSFETs are turned on fully to minimise their voltage loss and power dissipation.

For higher battery voltages, up to 32V, ZD1 and Q5 ensure that the gate voltage delivered by IC1b is limited to about 13V.

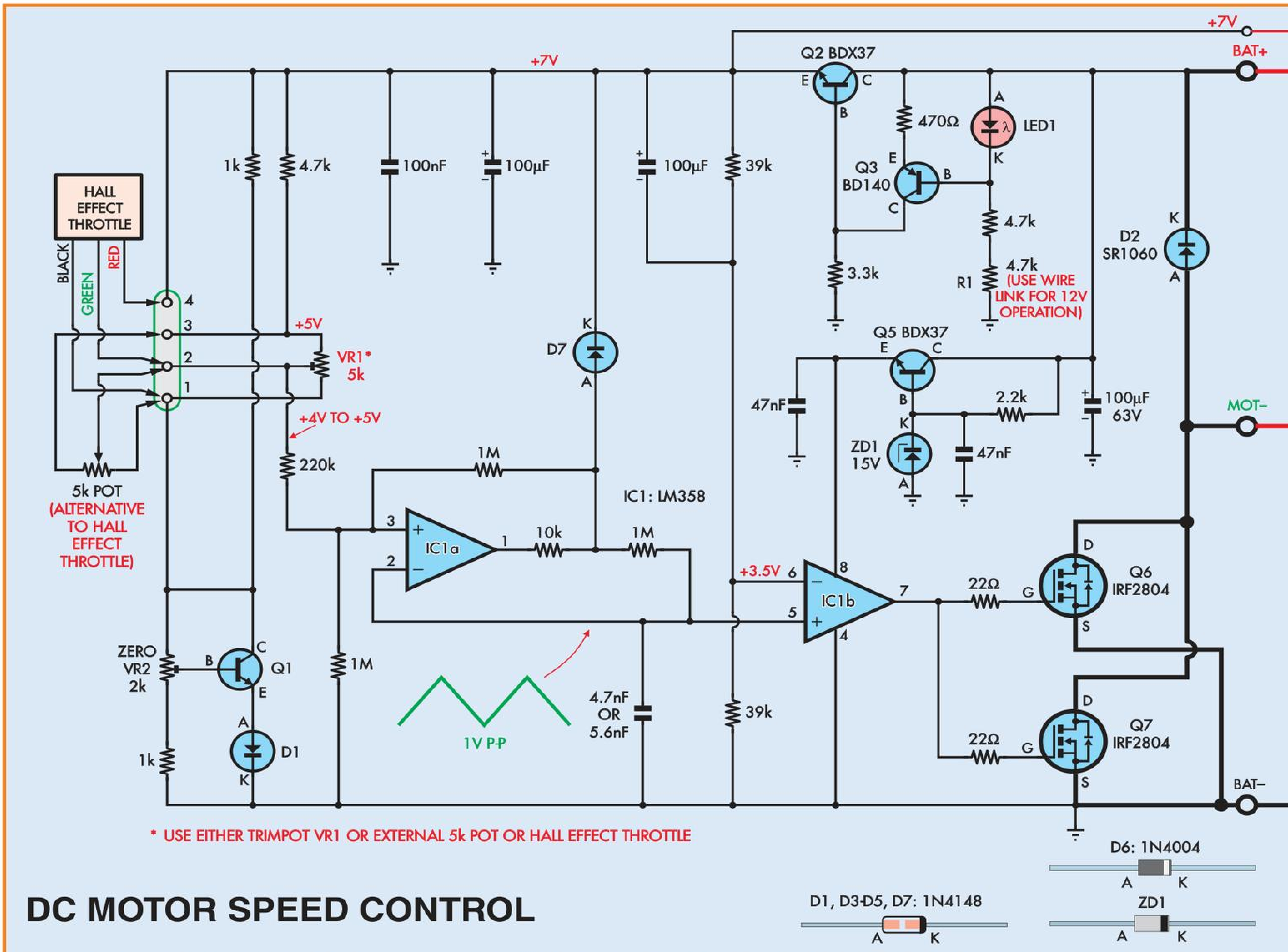
Note that the circuit shows three alternative throttle arrangements. The first is via trimpot VR1, which can be installed on the PC board. The second is for an external 5kΩ rotary speed control and the third is a twist grip Hall effect throttle. Only one of these options can be used at any one time.

Trimpot VR2 is a zero control. This is adjusted so that no voltage is applied to the motor at the minimum setting of the speed control.

Where To Buy Kits

Kits for this project are available from Oatley Electronics Pty Ltd, PO Box 89, Oatley, NSW 2223. Phone (02) 9584 3563. Website: **oatleyelectronics.com**

The reversible version (Cat. K275) costs $39 (£24.95) plus p&p, while the basic non-reversible (Cat. K275A) version is $24 (£15.36) plus p&p.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E
C
B
470Ω
A
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K
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4.7k
100nF
100µF
100µF
39k
Q3
BD140
E
B
C
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THROTTLE
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R1
4.7k
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LINK FOR 12V
OPERATION)
D2
SR1060
K
A
4
3
2
1
+5V
VR1*
5k
K
D7
A
Q5 BDX37
E
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2.2k
100µF
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MOT–
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THROTTLE)
IC1: LM358
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2
IC1a
1
10k
1M
+3.5V
6
8
IC1b
7
5
4
22Ω
G
D
S
Q6
IRF2804
ZERO
VR2
2k
B
C
Q1
E
1M
A
D1
K
1k
1V P-P
4.7nF
OR
5.6nF
39k
D
Q7
IRF2804
22Ω
G
S
BAT–
* USE EITHER TRIMPOT VR1 OR EXTERNAL 5k POT OR HALL EFFECT THROTTLE
D6: 1N4004
A
K
D1, D3-D5, D7: 1N4148
A
K
ZD1
A
K

DC MOTOR SPEED CONTROL

Fig.3: the circuit uses op amp IC1a to generate a 300Hz triangle wave. This is DC level shifted using the throttle and fed to comparator IC1b, which then generates the PWM square-wave pulses to drive MOSFETs Q6 and Q7 and the motor. Relays RLY1, RLY1a, RLY2 and RLY2a and their associated control circuit (IC2a to IC2d) provide the reversing feature.

Relay switching

Having a speed control on a motor is all very well, but in many applications you need to run the motor in forward or reverse mode. In order to do this on a DC motor, you need to swap the connections to the motor. In small motor circuits that could be done by a double-pole changeover switch, but when heavy currents are involved, relays are required.

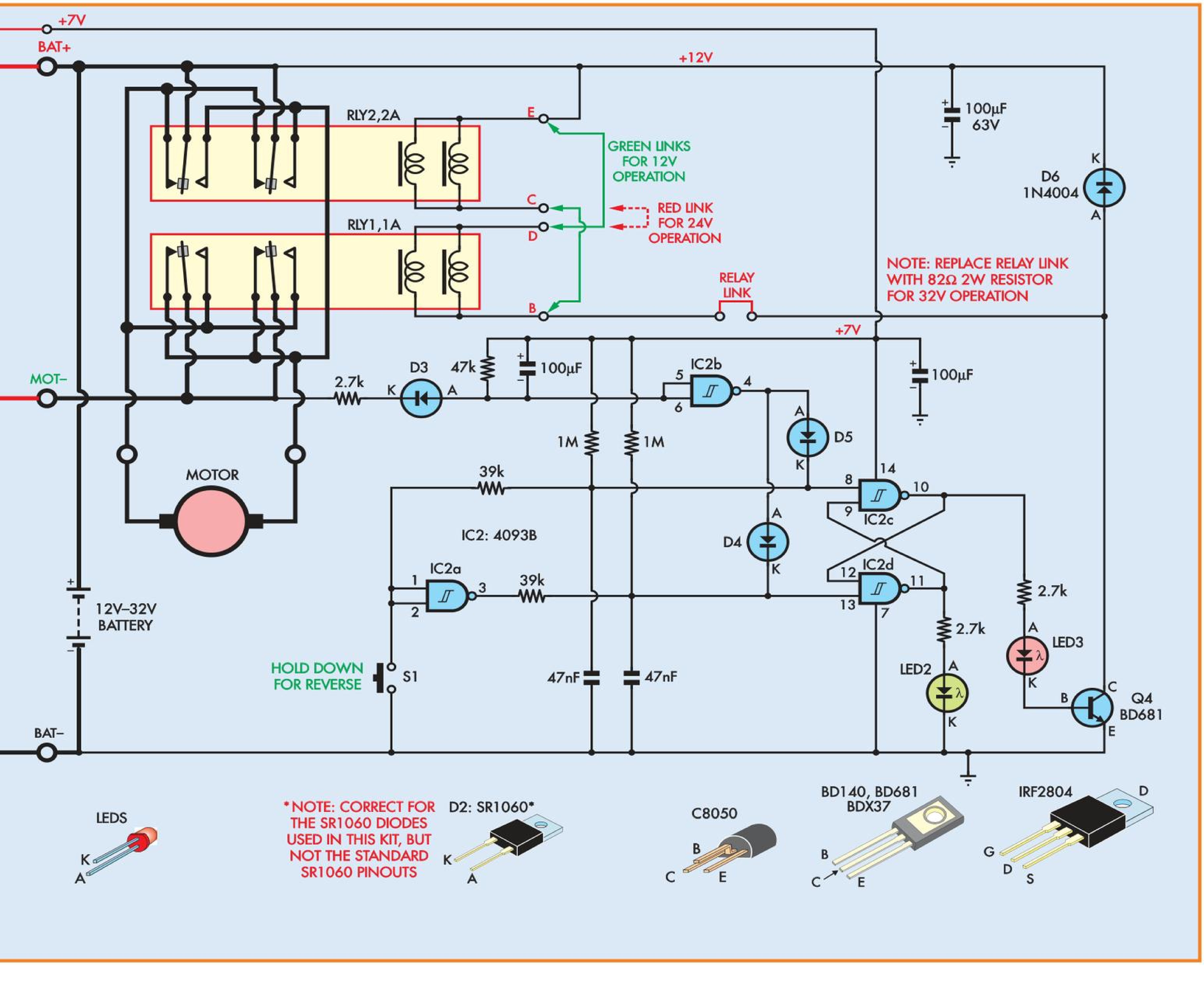
In the simplest arrangement, this can be done with a single large double-pole double-throw (DPDT) relay, or it could be done with two single-pole double-throw (SPDT) relays being switched simultaneously. This circuit is a little novel, in that it uses four SPDT relays, with the relays used as paralleled pairs to substantially increase the switch contact rating.

But there is a further refinement in that the heavy motor currents are never actually broken by the relay contacts. Instead, the relays are only operated when the voltage across the load is *zero* and, therefore, no current is flowing. This means that there will not be any contact arcing and accompanying contact erosion.

Relay logic controller

The relay logic controller is based on a 4093 quad 2-input Schmitt trigger NAND gate package. Gates IC2c and IC2d are connected as an RS flip-flop, which can be set or reset by having one of its inputs at pin 8 and pin 13 pulled low. Gate IC2c pin 10 controls the relay switching transistor Q4, so when this output is high, the relays are on and this provides the reverse direction for the motor.

Pin 1 and pin 2 of IC2a are normally pulled high by the series-connected 1MΩ and 39kΩ resistors, but when pushbutton switch S1 is pressed, the inputs are pulled low. When the motor is running, the drains of the MOSFETs (Q6 and Q7) are being pulsed low, and this repeatedly pulls the negative side of the 100µF capacitor connected to pin 5 and pin 6 of IC2b low, via diode D3. Hence, the output of IC2b is high and this pulls pin 8 and pin 13 high via diodes D5 and D4 respectively,


+7V
BAT+
+12V
RLY2,2A
RLY1,1A
E
C
D
B
GREEN LINKS FOR 12V OPERATION
RED LINK FOR 24V OPERATION
RELAY LINK
100µF 63V
K
D6 1N4004
A
NOTE: REPLACE RELAY LINK WITH 82Ω 2W RESISTOR FOR 32V OPERATION
+7V
MOT–
2.7k
D3
K
A
47k
100µF
IC2b
5
4
6
100µF
A
D5
K
1M
1M
MOTOR
39k
14
8
10
9
IC2c
IC2: 4093B
A
D4
K
12
IC2d
11
13
7
IC2a
1
3
2
39k
2.7k
2.7k
A
LED3
K
12V–32V BATTERY
HOLD DOWN FOR REVERSE
S1
47nF
47nF
LED2
A
K
C
B
Q4 BD681
E
BAT–
LEDS
K
A
*NOTE: CORRECT FOR THE SR1060 DIODES USED IN THIS KIT, BUT NOT THE STANDARD SR1060 PINOUTS
D2: SR1060*
K
A
C8050
B
C
E
BD140, BD681 BDX37
B
C
E
IRF2804
D
G
D
S

so the RS flip-flop cannot be toggled. Therefore motor direction cannot be changed while it is running.

When the MOSFETs are off, the motor stops running and pin 5 and pin 6 of IC2b are pulled high via the associated 47kΩ resistor, the 100µF capacitor being discharged. The motor direction cannot be changed during this discharge time, which is around 4s. This feature prevents sudden changes in the motor direction and this 4s period of time can be lengthened or shortened by respectively increasing or decreasing the value of the 47kΩ resistor.

Now, when the motor voltage (and current) is zero, the RS flip-flop can be toggled. So, to change from forward to reverse direction, you press pushbutton switch S1. This not only pulls IC2a's inputs low, but also pulls pin 8 of IC2c low and sets the flip-flop so that it turns on transistor Q4 and energises the two relay coils.

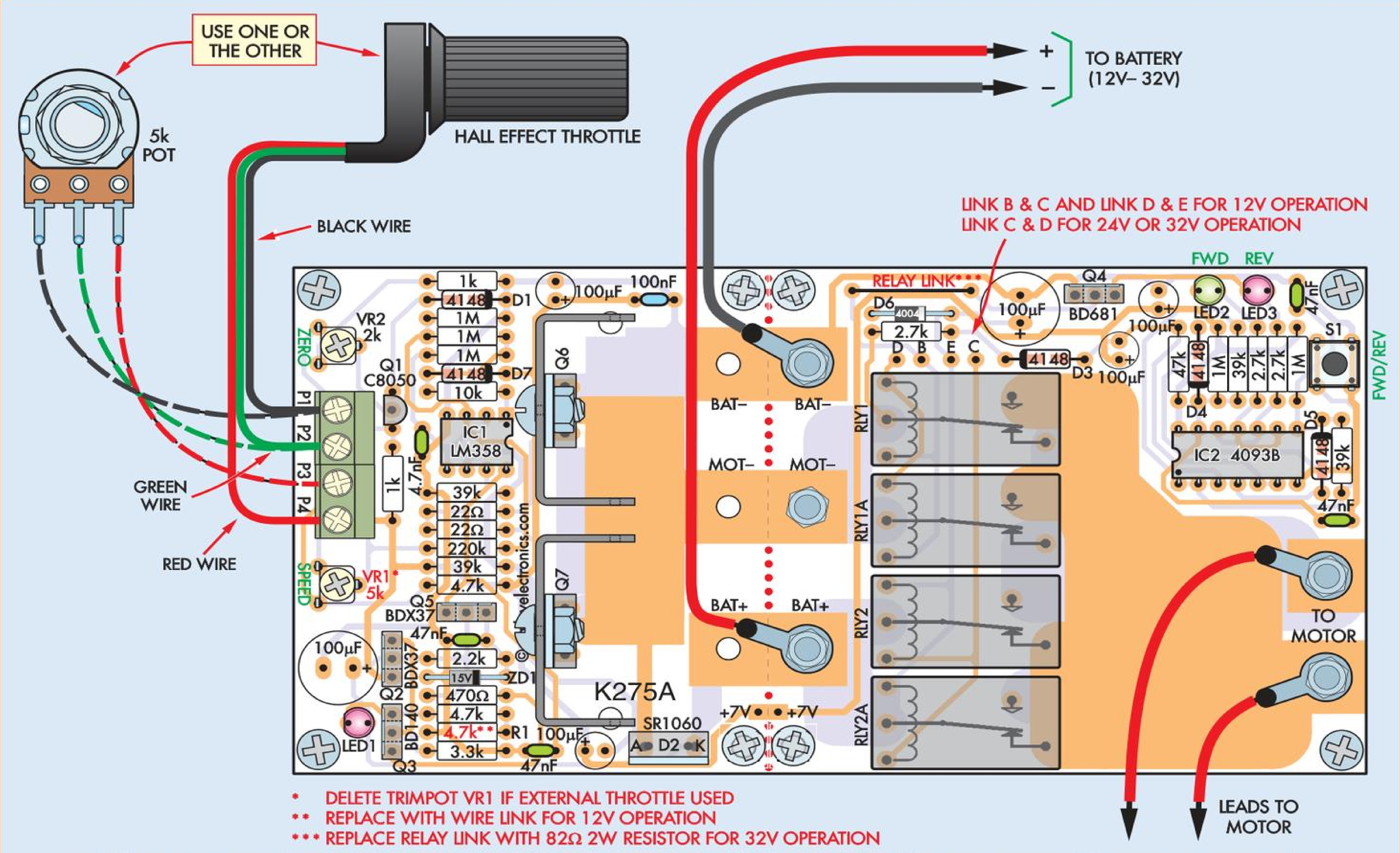
Note that as soon as you release pushbutton switch S1, it will immediately allow pin 1 and pin 2 of IC2a to go high again, and this will cause output pin 3 to go low. This will then reset the RS flip-flop, thereby turning off transistor Q4 and lighting LED2, which indicates forward direction. **Hence, for reverse operation, you need to keep the pushbutton pressed.**

This makes sense if you are making this speed control for an electric bi cycle and you only want reverse engaged for very limited time. **However, if the speed control needs to be in reverse mode for much longer periods, the pushbutton switch is not practical and you will need to substitute a standard SPST toggle switch.**

Building it

Both versions of the *DC Motor Speed Control* are available as kits from Oatley Electronics (see 'where to buy' panel on page 39). The reversible version is built on a double-sided PC board coded 864 (138mm × 70mm), while the non-reversible version (without the relays) uses a double-sided PC board coded 863 (60mm × 70mm).

Note that the parts layout on the latter is identical to the corresponding section on the fully-reversible version.


USE ONE OR THE OTHER
5k POT
HALL EFFECT THROTTLE
BLACK WIRE
GREEN WIRE
RED WIRE
+
–
TO BATTERY (12V– 32V)
LINK B & C AND LINK D & E FOR 12V OPERATION
LINK C & D FOR 24V OR 32V OPERATION
FWD REV
ZERO
VR2 2k
Q1 C8050
P1
P2
P3
P4
IC1 LM358
1k
4148
D1
1M
1M
1M
4148
D7
10k
100µF
100nF
Q6
Q7
4.7nF
39k
22Ω
22Ω
220k
39k
4.7k
SPEED
VR1* 5k
Q5 BDX37
47nF
100µF
BDX37
BD140
Q2
2.2k
15V
ZD1
470Ω
4.7k
4.7k**
R1
3.3k
LED1
Q3
100µF
47nF
K275A
SR1060
A D2 K
+7V +7V
BAT– BAT–
MOT– MOT–
BAT+ BAT+
RELAY LINK***
D6
4004
2.7k
D B E C
100µF
Q4 BD681
4148
D3
100µF
LED2 LED3
47nF
S1
FWD/REV
47k
4148
1M
39k
2.7k
2.7k
1M
D4
D5
IC2 4093B
4148
39k
47nF
RLY1
RLY1A
RLY2
RLY2A
TO MOTOR
LEADS TO MOTOR
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* DELETE TRIMPOT VR1 IF EXTERNAL THROTTLE USED
** REPLACE WITH WIRE LINK FOR 12V OPERATION
*** REPLACE RELAY LINK WITH 82Ω 2W RESISTOR FOR 32V OPERATION

Fig.4: follow this parts layout diagram to build both versions of the controller (the non-reversible version uses only those parts to the left of the red dotted line). Note that some of the parts and linking options vary, depending on whether the controller is to be powered from 12V, 24V or 32V.

Fig.4 shows the assembly details. If you are building the non-reversible version, just follow the layout to the left of the red dotted line. Conversely, for the reversible version, you will need to assemble the entire board.

Begin construction by installing the resistors and diodes. Check each resistor using a DMM (digital multimeter) before installing it. Note that resistor R1 (4.7kΩ, near LED1) should be replaced with a wire link for 12V operation.

Conversely, you will need to install the resistor if you intend operating the controller from 24V or 32V.

Be sure to install the correct diode type at each location and check that they are all correctly orientated. Diode D2 (SR1060) goes in with its metal tab adjacent to the edge of the PC board.

Once these parts are in, install the capacitors and IC sockets. Check that the electrolytics are all correctly orientated and make sure that the sockets go in with their notched ends positioned as shown.

Transistor mounting

Now for the transistors. These should all be pushed down onto the PC board as far as they will comfortably go before soldering their leads. Use the correct type at each location and take care with their orientation – the metal faces of Q2 and Q3 face the 100µF capacitor and LED1 respectively, while Q5's metal side faces the adjacent 4.7kΩ resistor. Q4 goes in with its metal face towards the edge of the PC board.

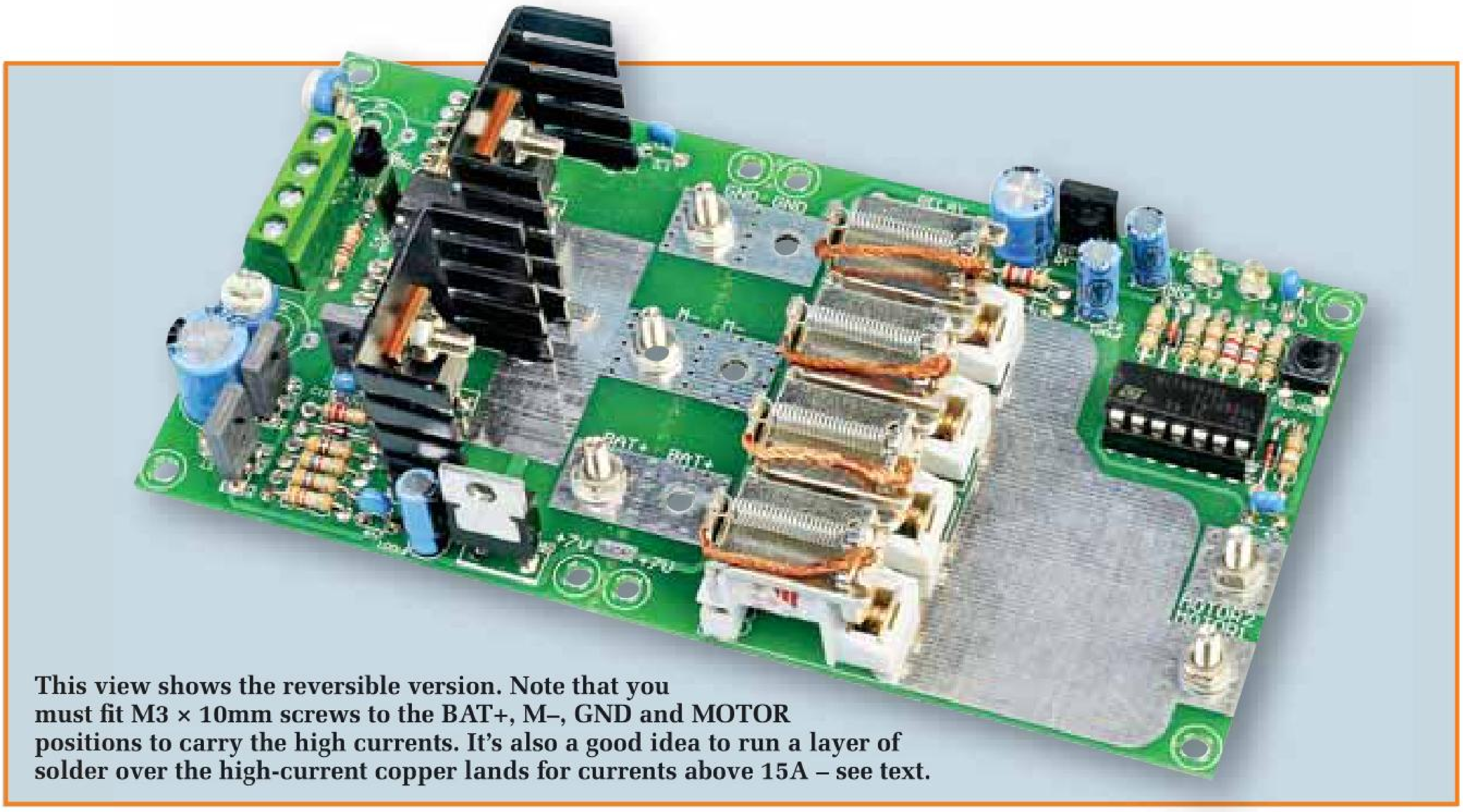
Table 1: Linking options

Supply rail	Relay configuration	Relay link	Resistor R1
12V	Link B / C, link D / E	Wire link	Wire link
24V	Link C and D	Wire link	4.7kΩ
32V	Link C and D	82Ω 2W resistor	4.7kΩ

The two power MOSFETs (Q6 and Q7) should now be loosely attached to their U-shaped heatsinks using M3 × 10mm machine screws, washers and nuts. That done, install each assembly in position and push it down until the bottom edge of its heatsink rests against the PC board. The heatsink tabs should go through the holes in the board and these should be bent using pliers to hold the assemblies in position while you solder the device leads.

Bending the heatsink tabs will also make the assemblies more secure, particularly if the board will later be subject to vibration. Once everything is in place, tighten the screws that secure the MOSFET tabs to the heatsinks.

Trimpot VR2 (2kΩ) can be installed, and the board has been designed to accept either a horizontal or vertical trimpot. **The same goes for trimpot VR1 (5kΩ), but you must leave this part out if you are using an external throttle to control motor speed.** VR1 is installed only if you are using the controller to set a fixed motor speed (ie, no external throttle).



This view shows the reversible version. Note that you must fit M3 × 10mm screws to the BAT+, M–, GND and MOTOR positions to carry the high currents. It's also a good idea to run a layer of solder over the high-current copper lands for currents above 15A – see text.

The two ICs can now be plugged into their sockets (note: they face in opposite directions) and the relays installed. These relays will only fit one way and you should use generous amounts of solder on their contact pins since they can carry quite high currents.

Forward/reverse switch

Pushbutton switch S1 is the Forward/Reverse switch. This should only be installed on the board if you want a switch that you hold down for reverse operation (ie, if you only want reverse for a short time).

However, as stated earlier, you will need to substitute a standard SPST toggle switch if you want reverse for extended periods of time. In that case, just connect the switch contacts to the appropriate copper pads on the PC board using flying leads.

Linking options

There are several linking options and component changes, depending on whether you are operating the controller from 12V, 24V or 32V. Table 1 shows the details.

First, on the reversible version, you will need to install the 'relay link' at the top of the board (above the relays). This is simply a wire link for operation up to 24V, but this *must* be replaced with an 82Ω 2W resistor (not supplied with the kit) for 32V operation.

Similarly, you also need to link the relay coils for either parallel or series operation, depending on the supply voltage. For 12V operation, use *separate* wire links to connect points B and C together, and points D and E together. Alternatively, for 24V or 32V operation, connect points C and D together (don't forget to replace the relay link with an 82Ω 2W resistor for 32V operation – see above).

Note that the two links installed for 12V operation overlap each other. Be sure to position them so that they cannot short together (or sleeve them with heatshrink, or use insulated wire).

The final option concerns one of the 4.7kΩ resistors (R1) in series with LED1. As stated previously, this *must* be replaced with a wire link for 12V operation.

High-current connections

All connections to the motor and battery must be run via crimped eyelet connectors, which are attached to the PC board using M3 × 10mm machine screws, washers and nuts. In addition, if building the reversible version, **you must also fit an M3 × 10mm screw, washer and nut to the MOT– hole position, immediately to the left of relay RLY1A (see Fig.4).**

That last step is important because the screw through the MOT–hole helps carry the heavy currents that flow through the motor and power MOSFETs Q6 and Q7. The same goes for the machine screws that are used to terminate the eyelets for the battery and motor connections.

In short, you must have machine screws running through the BAT+, BAT–, MOT– and TO MOTOR holes to carry the heavy currents involved. Don't just rely on the through-hole plating of the board – it could 'fuse' under high-current conditions.

If you are building the smaller non-reversible version, use the alternative BAT–, MOT– and BAT+ connections shown on Fig.4. The motor is connected between MOT– and BAT+. As before, all connections must be made via crimped eyelet connectors, which are attached using M3 × 10mm screws, washers and nuts.

Make sure that the leads are adequately rated to carry the currents involved. *Generally, this will involve using heavy-duty cabling rated at 15A or greater if required.*

Finally, for currents above about 15A, run a thick layer of solder over all the high-current copper lands on the PC board. This must be done on both sides of the board and involves the lands running to the power MOSFETs, the motor and battery connections, and the relay contacts.

Testing

When the assembly is complete, check your work very carefully. Any mistakes in component placement or polarity could result in damage when the power supply is connected. **Supply polarity is also crucial – getting it wrong can seriously damage the unit.**

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The basic non-reversible version is shown here, together with the optional handle-bar type (Hall effect) throttle. Be sure to omit trimpot VR1 from the board if you intend using an external throttle – see text.

Parts List (Non-Reversible)

1 PC board, code 863, available from the *EPE PCB Service*, size 60mm × 70mm
2 PC-mount 2-way screw terminal blocks
1 8-pin DIP IC socket
5 M3 × 10mm machine screws
5 M3 nuts
5 M3 washers
2 finned u-shape heatsinks
Tinned copper wire for links

Semiconductors
1 LM358 dual op amp (IC1)
1 C8050 *NPN* transistor (Q1)
2 BDX37 *NPN* transistor (Q2,Q5)
1 BD140 *NPN* transistor (Q3)
2 IRF2804 MOSFETs (Q6,Q7)
1 15V Zener diode (ZD1)
2 1N4148 signal diodes (D1,D7)
1 SR1060 Schottky diode (D2)
1 red 3mm LED (LED1)

Capacitors
1 100µF 63V electrolytic
2 100µF 16V electrolytic
1 100nF monolithic
2 47nF monolithic
1 4.7nF greencap

Resistors (0.25W 0.5%)
3 1MΩ
1 220kΩ
2 39kΩ
1 10kΩ
3 4.7kΩ
1 3.3kΩ
1 2.2kΩ
2 1kΩ
1 470Ω
2 22Ω
1 5kΩ trimpot (VR1)
1 2kΩ trimpot (VR2)

If everything checks OK, connect a 12V battery (or other high-current DC power supply), but do not connect the motor yet. Now check that +7V is present on the emitter of transistor Q1. If it is, set the throttle (either an external pot or VR1) to minimum and monitor the voltage at pin 7 of IC1. This voltage should vary as you vary the throttle. If you have an oscilloscope, you can check that the PWM duty cycle varies, as shown on the scope screen shots of Fig.1 and Fig.2.

Next, set the throttle to minimum, connect a motor and connect your DMM (set to volts) across the motor's terminals. Adjust trimpot VR2 for a reading of 0V – this will zero the controller's output when the throttle is at minimum. Alternatively, you can set it to give a minimum motor speed.

Now adjust the throttle. The motor should start, respond to the adjustments, and the DMM should indicate corresponding voltage variations. ***EPE***

Parts List (Reversible version)

1 PC board, code 864, available from the *EPE PCB Service*, size 138mm × 70mm
1 PC-mount tactile switch (S1)
2 PC-mount 2-way screw terminal blocks
1 5kΩ trimpot (VR1)
1 2kΩ trimpot (VR2)
1 8-pin DIP IC socket
1 14-pin DIP IC socket
4 12V 30A relays
7 M3 × 10mm machine screws
7 M3 nuts
7 M3 washers
2 finned u-shape heatsinks
Tinned copper wire for links

Semiconductors
1 LM358 dual op amp (IC1)
1 4093 quad 2-input NAND gate (IC2)
2 red 3mm LEDs (LED1, LED3)
1 green 3mm LED (LED2)
1 C8050 *NPN* transistor (Q1)
2 BDX37 *NPN* transistor (Q2,Q5)
1 BD140 *NPN* transistor (Q3)
1 BD681 *NPN* Darlington transistor (Q4)
2 IRF2804 MOSFETs (Q6,Q7)
1 15V Zener diode (ZD1)
5 1N4148 small signal diodes (D1,D3-D5,D7)
1 SR1060 Schottky diode (D2)
1 1N4004 1A diode (D6)

Capacitors
2 100µF 63V electrolytic
4 100µF 16V electrolytic
1 100nF monolithic
4 47nF monolithic
1 4.7nF greencap

Resistors (0.25W, 5%)
5 1MΩ
1 220kΩ
1 47kΩ
4 39kΩ
1 10kΩ
3 4.7kΩ
1 3.3kΩ
3 2.7kΩ
1 2.2kΩ
2 1kΩ
1 470Ω
2 22Ω

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Jump Start

By Mike and Richard Tooley

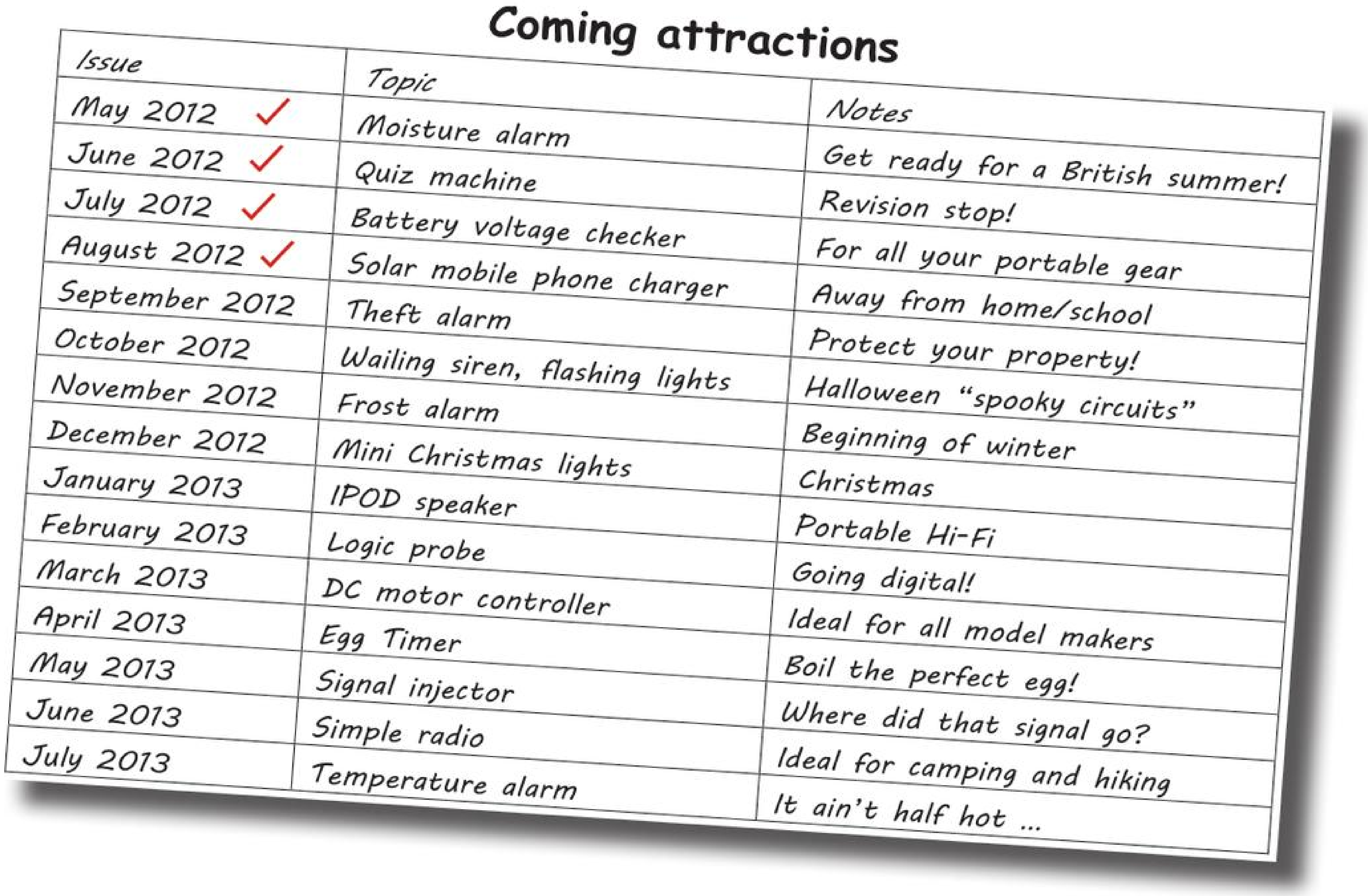
Design and build circuit projects dedicated to newcomers, or those following courses taught in schools and colleges.

WELCOME to *Jump Start* – our new series of seasonal 'design and build' projects for newcomers. *Jump Start* is designed to provide you with a practical introduction to the design and realisation of a variety of simple, but useful, electronic circuits. The series will have a seasonal flavour, and is based on simple, easy-build projects that will appeal to newcomers to electronics, as well as those following formal courses taught in schools and colleges.

Each part uses the popular and powerful 'Circuit Wizard' software package as a design, simulation and printed circuit board layout tool. For a full introduction to Circuit Wizard, readers should look at our previous *Teach-In series*, which is now available in book form from Wimborne Publishing (see *Direct Book Service* pages 75-77 in this issue).

Each of our Jump Start *circuits include the following features:*

- ***Under the hood*** – provides a little gentle theory to support the general principle/theory behind the circuit involved
- ***Design notes*** – has a brief explanation of the circuit, how it works and reasons for the choice of components
- ***Circuit Wizard*** – used for circuit diagrams and other artwork. To maximise compatibility, we have provided two different versions of the Circuit Wizard files; one for the education version and one for the standard version (as supplied by *EPE*). In addition, some parts will have additional files for download (for example, templates for laser cutting)
- ***Get real*** – introduces you to some interesting and often quirky snippets of information that might just help you avoid some pitfalls
- ***Take it further*** – provides you with suggestions for building the circuit and manufacturing a prototype. As well as basic construction information, we will provide you with ideas for realising your design and making it into a complete project
- ***Photo Gallery*** – shows how we developed and built each of the projects.



Coming attractions

Issue	Topic	Notes
May 2012 ✓	Moisture alarm	Get ready for a British summer!
June 2012 ✓	Quiz machine	Revision stop!
July 2012 ✓	Battery voltage checker	For all your portable gear
August 2012 ✓	Solar mobile phone charger	Away from home/school
September 2012	Theft alarm	Protect your property!
October 2012	Wailing siren, flashing lights	Halloween "spooky circuits"
November 2012	Frost alarm	Beginning of winter
December 2012	Mini Christmas lights	Christmas
January 2013	IPOD speaker	Portable Hi-Fi
February 2013	Logic probe	Going digital!
March 2013	DC motor controller	Ideal for all model makers
April 2013	Egg Timer	Boil the perfect egg!
May 2013	Signal injector	Where did that signal go?
June 2013	Simple radio	Ideal for camping and hiking
July 2013	Temperature alarm	It ain't half hot ...

Solar-Powered Charger

In this month's Jump Start *we shall be designing and building a* Solar-Powered Charger *suitable for use with battery-powered equipment, including some MP3 players and mobile phones that need a low-rate, 5V charging source.*

It is designed to provide sufficient current to supply a nominal 5V battery with charging currents of up to 150mA in bright sunshine but, if it happens to be cloudy and there's insufficient sunlight available, the charger is capable of supplying current from its own internal battery, which can be topped-up whenever there's sufficient light available.

Under the hood

The simplified block schematic of our *Charger* is shown in Fig.1. The prime mover behind our charger is a solar battery made up from individual solar cells, each of which is rated for a nominal off-load output of 1V, and a short-circuit current of 150mA when placed in full sun.

For practical purposes, we will need to supply our charger control circuit with an input voltage of at least 6.3V and ideally 8V, or more. To achieve this we will need to use eight or ten cells connected in series.

However, we need to be mindful that the maximum current that this arrangement will be able to supply is 150mA and this may mean that a longer connection time will be required to achieve full charge. A ten cell series-connected arrangement provides us with a charging voltage that will typically vary from about 6.3V to 8.3V with a charging current of around 125mA, depending on the intensity of the sunlight. You might be wondering why the ten cells used in our solar battery produce an output of only 6V to 8V when connected to a load. This is because each solar cell has some internal resistance that effectively limits the current that it can supply, and reduces its voltage when 'on-load'.

In fact, all batteries and voltage sources have internal resistance. We can't see or touch internal resistance, but it's there inside the voltage source and it can have a huge impact both on the amount of current that can be delivered, as well as the terminal voltage that appears when a cell is connected to a load. You can check this out with Circuit Wizard using an arrangement like the one shown later in 'Get real'.

While the Solar-Powered Charger has been successfully tested with several 'mobile phone and MP3 players, neither Wimborne Publishing nor the authors can guarantee that the unit is fit for use with a particular item/brand of portable equipment.

Before connecting the unit to any piece of equipment, it is *essential* to observe the correct polarity and also to ensure that the equipment is designed to be charged from a nominal 5V source at a low charge rate. The Solar-Powered Charger is not designed to replace an 'intelligent' high-rate charger.

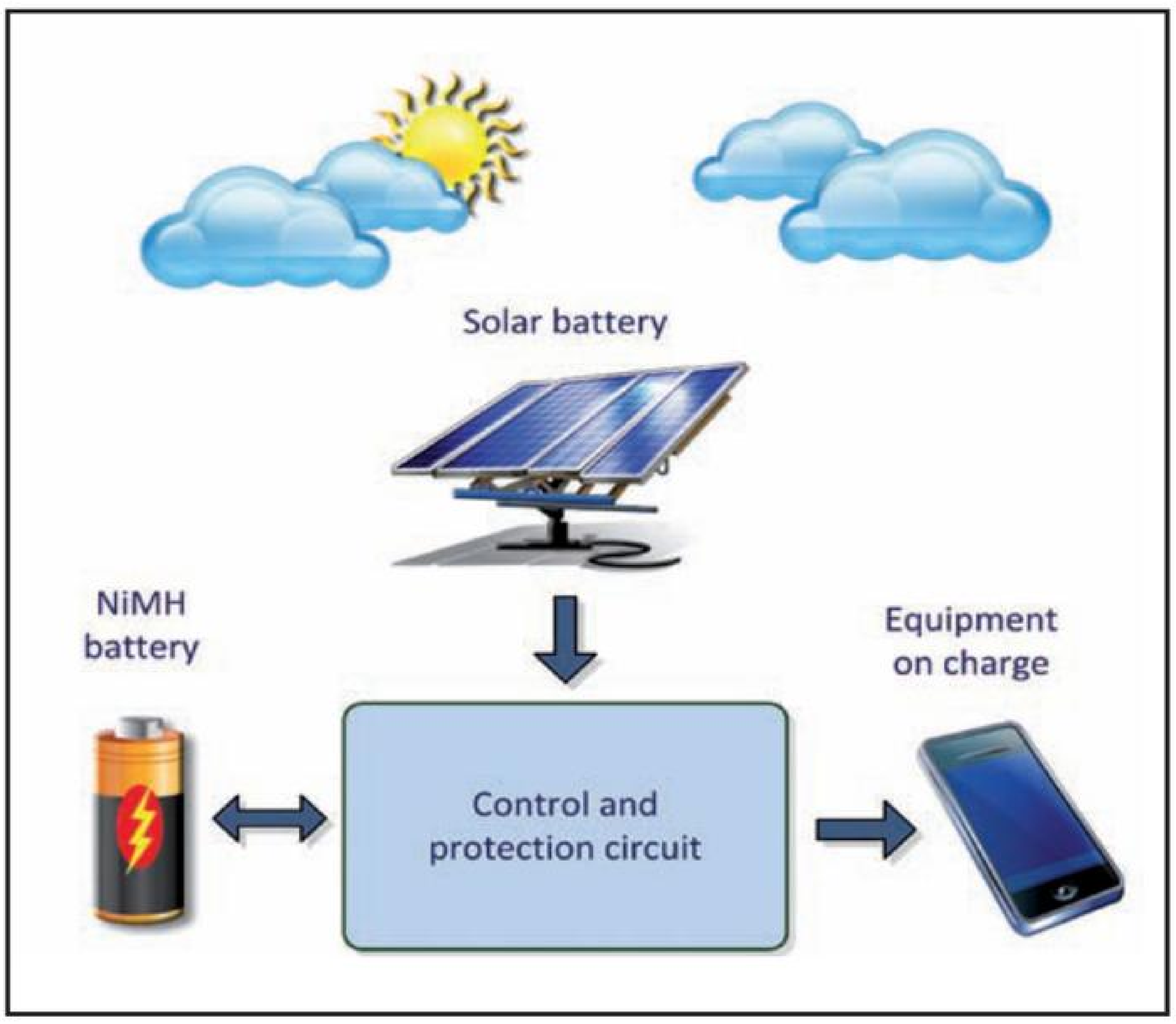


Fig.1. Simplified block diagram of our Solar-Powered Charger

Design notes

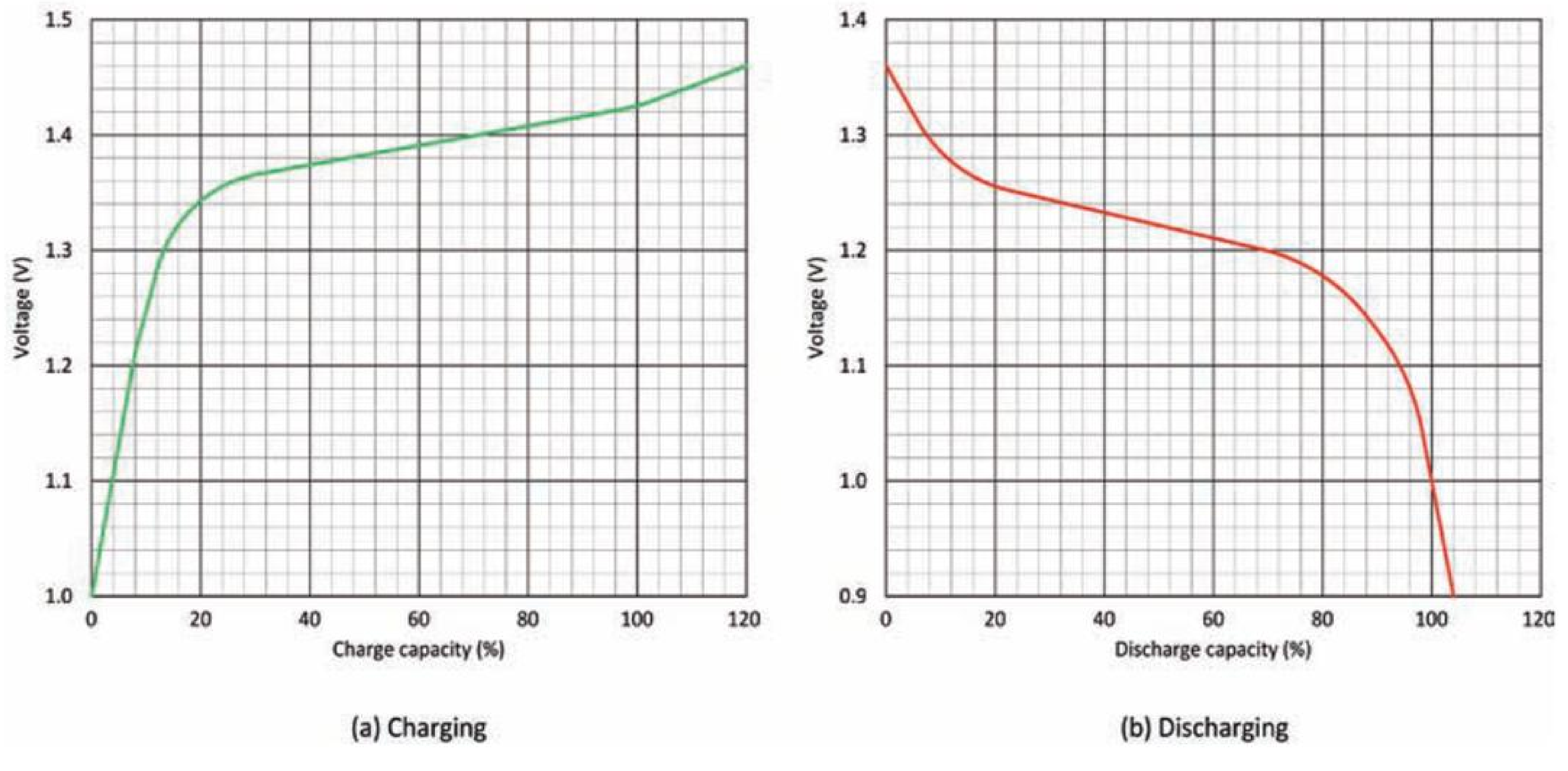
There are two important aspects to the design of this month's *Jump Start* project. The first of these relates to the characteristics of the nickel metal hydride (NiMH) batteries that are frequently used in portable equipment. The second aspect is concerned with the wide variation in light level that might be experienced by a portable solar-powered charging system. We will examine these two aspects in turn.

Battery capacity

Electronic engineers and designers are frequently concerned with how long a battery will supply the current needed to run a particular piece of equipment. The length of time is determined by the capacity of the battery and the rate at which it is discharged. This 'capacity' is denoted by C and is expressed in ampere-hours (Ah) or milliampere-hours (mAh). For example, a battery rated at 800mAh could be expected to supply a current of 800mA for one hour, 400mA for two hours, 200mA for four hours, and so on.

Batteries are usually specified for use at sub-multiples of the C rate. For example, C/2 would correspond to a battery rated at 800mAh being discharged to its specified 'end-voltage' when supplying a load current of 400mA for two hours. Alternatively, C/10 would correspond to the ability to supply 80mA to a load for ten hours, and so on.

The end-voltage of a typical NiMH cell is usually quoted as 1V. Thus, a four-cell NiMH battery will have a nominal end-voltage of 4V (but note that its initial voltage will be significantly higher than this!).



(a) Charging

(b) Discharging

Fig.2. Charge and discharge characteristics for a typical NiMH cell when used at the C/10 rate

To understand what happens when a battery is first charged and then discharged take a look at Fig.2. This shows the charge and discharger characteristics for a typical NiMH cell when operated at the C/10 rate (the curves are broadly similar for other rates).

On charge

When placed on charge, as shown in Fig.2(a), the initially exhausted cell will have a terminal voltage of 1V, or so, and this will rise very rapidly to greater than 1.3V before increasing more gently until it eventually exceeds 1.4V at the end of the charging cycle. When fully charged, the battery voltage then rises more quickly and its internal temperature also increases.

Automatic 'fast chargers' that charge at relatively high-C rates (eg, 1C or 2C) often use one or both of these effects in order to discontinue charging and avoid permanent damage to cells due to possible over-charging.

Discharge

When a NiMH cell is discharged, following an initial rapid fall in terminal voltage from about 1.4V to around 1.25V, as shown in Fig.2(b). The output voltage remains reasonably constant and then falls rapidly as the end-voltage (approximately 1V) is approached. As the cell becomes exhausted, the terminal voltage falls at an increasing rate, at which point the equipment in which the battery is used will normally produce a 'low battery' indication.

The industry-standard rated voltage of a NiMH cell is 1.2V. This value is the nominal voltage of a cell that is discharged at a rate of C/10, at a temperature of 25°C (77°F) to an end voltage of 1V.

It is worth noting that the delivered capacity and nominal voltage of a battery are dependent on the rate of current at which a battery is discharged. For NiMH batteries, there is no significant effect on capacity and voltage for discharge rates below 1C. A reduction in the nominal voltage occurs for discharge rates between 1C and 3C for all the NiMH cell sizes, with the exception of the more expensive high-rate series of cells.

Variations in light level

A vitally important factor for consideration – particularly for those living in the UK – is that the amount and intensity of sunlight is both unpredictable and extremely variable. Our *Solar-Powered Charger* should work well in the Sahara Desert, but for use in the UK we will need to take into consideration what will happen over a complete range of ambient lighting conditions, see Table 1.

Table 1: Typical output from a small solar battery (note that the 'conditions' are subjective and also that our UK climate often suffers from rapid fluctuations in the actual level of sunlight as the sun goes in and out of the clouds!)

Conditions	Typical solar battery output
Bright sun at mid-day	125mA
Morning or evening sun	95mA
Slightly overcast	45mA
Heavily overcast	15mA
Dense cloud	2mA
Darkness	Nil

The information in Table 1 illustrates the problem of not having a constant energy source available to charge a battery. What we thus need is a secondary source of power in the shape of an internal battery that can be continuously 'topped-up' whenever sufficient light is available. This battery can be charged at a 'safe' C/10 rate, thus ensuring a reasonably long life, without the risk of over-charging.

The current available from the solar battery needs to be delivered to the equipment on charge (for example, an MP3 player) and, depending upon the actual light level at any time, some current can also be applied to the internal battery in order to maintain its charge, so that its stored energy can become available for use in times of darkness. Assuming that the internal battery has a modest capacity of, say, 800mAh we might arrive at the charging scheme shown in Table 2, which takes into account the limited output of an inexpensive solar battery.

In order to cater for the variations in sunlight and the need to 'top-up' our internal battery (the two design considerations that we mentioned earlier) we need a control unit that will:

(a) Limit the charging current
(b) Protect the equipment being charged against reverse polarity and excessive charging voltage
(c) Protect the internal battery against short-circuit
(d) Divide the current between the equipment on charge and the internal battery and effectively shut-off the solar battery in times of darkness so that charging can continue using the internal battery.

Get real

You can easily check out the effect of internal resistance on the performance of a simple charging arrangement using Circuit Wizard, as shown in Fig. 3. The power source for the charger is represented by the constant voltage

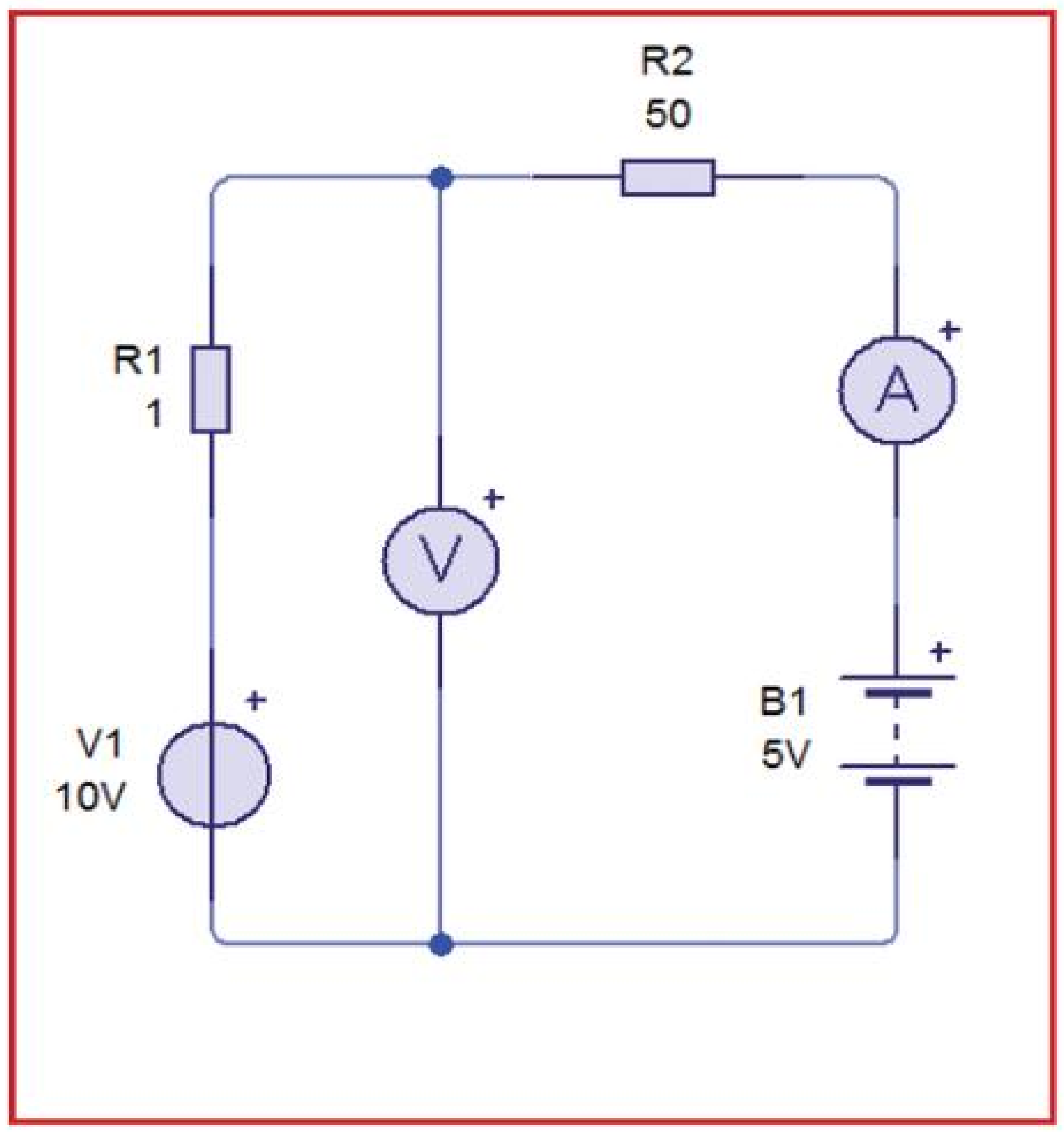


Fig.3. Using Circuit Wizard to investigate the effect of internal resistance on a battery charging arrangement

Table 2: A possible charging scheme for a Solar-Powered Charger

Conditions	Solar battery output	Output to equipment being charged	Internal battery (800mAh nominal)
Sunny	120mA	80mA	40mA (charge)
		Not connected	120mA (charge)
Overcast	60mA	50mA	10mA (charge)
		Not connected	60mA (charge)
Cloudy	5mA	45mA	40mA (discharge)
		Not connected	5mA (charge)
Dark	Nil	40mA	40mA (discharge)
		Not connected	Nil

source, V1, and its internal resistance is represented by R1. The series current-limiting resistor, R2, is used to determine the charging rate and the ammeter, A, indicates the current that is actually supplied to the battery on charge, B1.

If the charging source had been perfect, R1 would be zero, in which case the charging current (ie, the design value determined just by R2 and the voltages provided by V1 and B1) would be exactly 100mA. Try varying the value of R1 and noting the effect on the charging current. With an internal resistance of 5Ω, the charging current will fall to 91mA, and at 10Ω it will fall to 83mA.

Current limiting

Circuit Wizard can also be used to investigate the current-limiting arrangement used in the *Solar-Powered Charger*. This circuit is shown in basic form in Fig.4. The circuit is designed to limit the current flowing in the collector of Q1 to around 70mA. Try varying the value of B1 over the range 6V to 16V and noting the effect on the current. If you have time, try replacing R1 with 20Ω and repeating the measurements. You should note that the current is now limited to about 35mA.

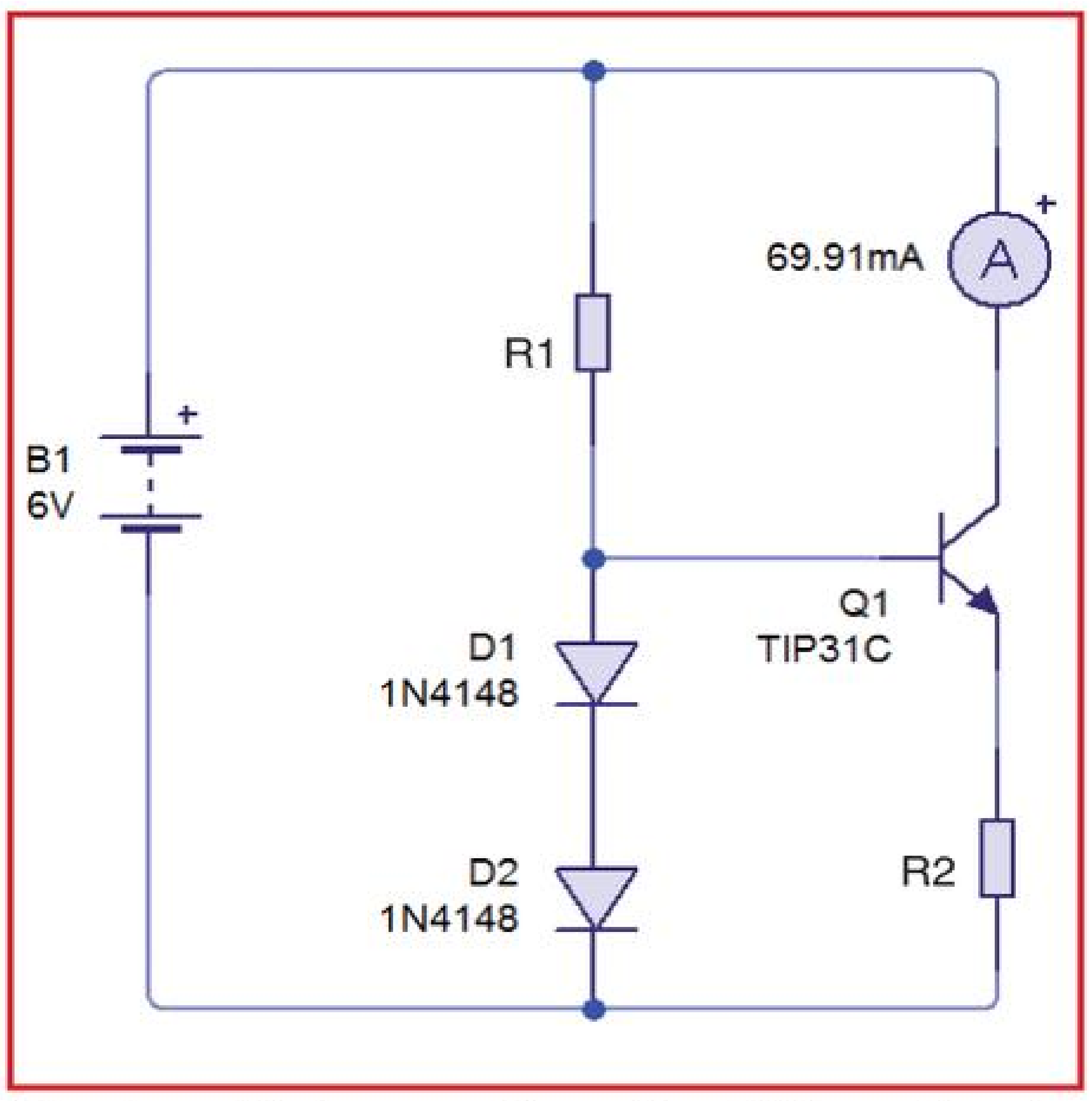


Fig.4. Using Circuit Wizard to investigate the operation of a constant current source

A note regarding Circuit Wizard versions

Circuit Wizard is available in several variants; Standard, Professional and Education (available to educational institutions only). Please note that the component library, virtual instruments and features available do differ for each variant, as do the licensing limitations. Therefore, you should check which is relevant to you before purchase. During the Jump Start *series we aim to use circuits/features of the software that are compatible with the latest versions of all variants of the software. However, we cannot guarantee that all items will be operational with every variant/version.*

Solar-Powered Charger – using Circuit Wizard

AS WITH all of our *Jump Start* circuits, we've given you the underpinning theory, putting it into practice using circuit simulation and converting it to a PCB design. The Circuit Wizard software that we've used throughout the series makes this process really simple and great fun. We recommend after the tutorials you enter the circuits and convert them to your very own PCB designs.

However, if this isn't your bag, you can simply use our artwork to prepare your boards or download our own Circuit Wizard files from the *Jump Start* website at: **www.tooley.co.uk/epe** – Don't forget, if you'd just prefer a pre-made PCB, you can purchase these from the *EPE* Magazine's *PCB Service* (see page 78).

Circuit Wizard

Now we've looked at how it all works – let's start putting it all together into a practical circuit that we can make into a finished product. Our practical circuit is shown in Fig.5.

The solar cells are simulated by B1 and the phone/gadget on charge is simulated by B3. Try experimenting with the value of B1 to mimic the changing light levels. In very bright sun you might achieve up to 8V, while around 5V to 6V is typical when it's more overcast. Note that compared with the practical circuit, the results of the simulation do seem to yield a higher output voltage – don't panic; you should expect just above 5V on the real thing.

Fig.6 shows our solar charger circuit ready to be converted to a PCB. We've removed the meter and replaced the batteries that we used when simulating with screw terminals. We can now go ahead and convert to PCB following the process we described in the previous editions of the *Jump Start* series.

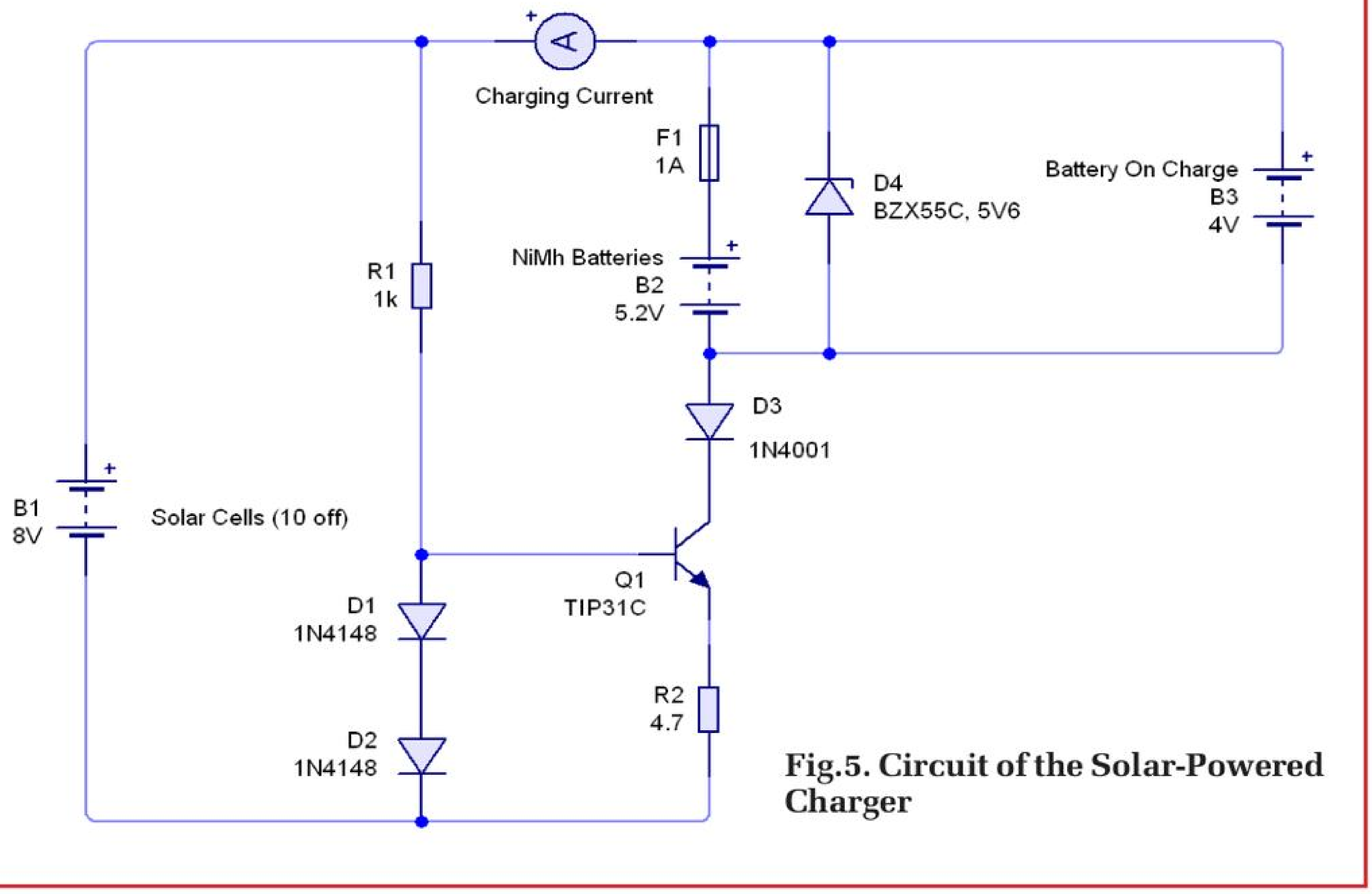


Fig.5. Circuit of the Solar-Powered Charger

Fuseholder

Our version of Circuit Wizard doesn't have on-board PCB mounting fuseholders as standard, and when converting to PCB a standard two-pin screw connector is inserted by default. This is fine if you wish to use a wired off-board fuseholder.

In fact, a panel mounted variety would be ideal if you were using a standard box enclosure. However, as we intend to use an 'open' enclosure, and wish to minimise off-board connections by using a fuse mounted directly on the PCB, we need to make a little tweak to our PCB.

The 'correct' way of solving this problem would be to create a new component outline and add it to the component library. However, users in schools/colleges often do not have the appropriate rights to access and/or amend the component database files, due to the way the computers are locked down. Therefore, we'll use a simple (but quick and equally effective!) tweak.

Our fuseholder has a pin pitch (the distance between the two pins) of 0.9in (23mm). When designing our PCB we will convert the fuse across as a simple screw terminal, but add an additional pad to accept one of the legs of the much wider component (see Fig.7). In our case we added the new pad along the top horizontal track but left the original component correctly connected so that it does not flag up as an error when verifying the PCB design

The printed circuit board (PCB) design, component layout and copper track artwork produced using Circuit Wizard is shown in Fig.8. This board is just 33mm × 66mm, and can be purchased from the *EPE PCB Service*, code 860.

Once you've designed your PCB, it's always worth running a 'Quality Check' (Fig.9). This really useful Circuit Wizard feature will check your PCB design against your original

You will need...

- 1 PCB, code 860, available from the *EPE PCB Service*, size 33mm × 66mm
- 10 1V 150mA small solar panels (Rapid 37-0438 **www.rapidonline.com**). Other cells/panels can be used provided they can be configured to supply about 10V at a current of 100mA in bright sun
- 1 battery holder for four AA cells, plus battery clip
- 3 Two-way PCB mounting terminal blocks
- 4 NiMH AA cells of 800 to 1200mAh capacity
- 1 20mm PCB mounting fuseholder
- 1 1A quick blow 20mm fuse

Semiconductors

- 2 1N4148 diodes (D1 and D2)
- 1 1N4001 diode (D3)
- 1 BZ55C5V6 Zener diode (D4)
- 1 TIP31 *NPN* transistor (Q1)

Resistors

- 1 1kΩ (R1) 1 4.7Ω (R2)

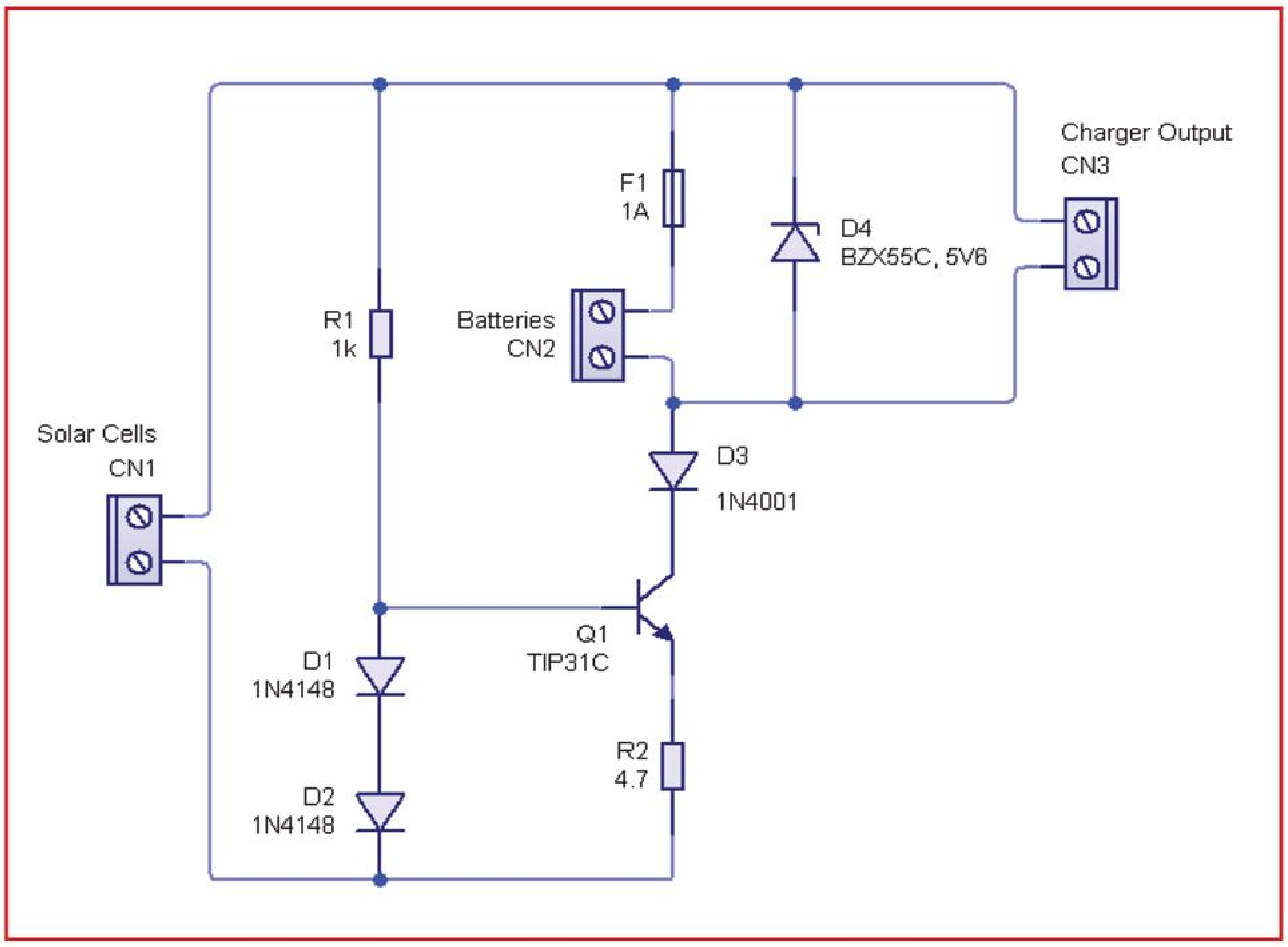


Fig.6. Circuit ready for conversion to a PCB layout

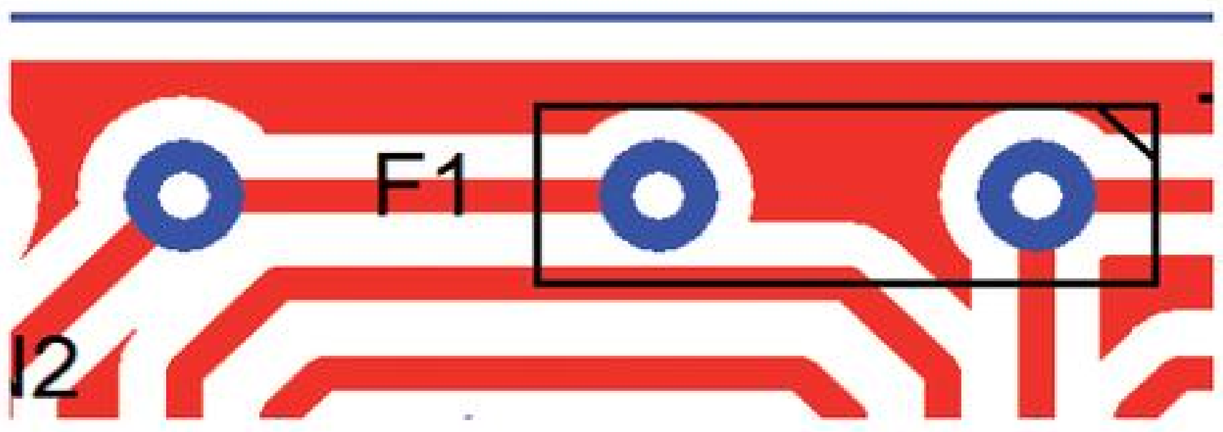


Fig.7. Added pad to accommodate the PCB mounting fuseholder

CIRCUIT WIZARD

By integrating the entire design process, Circuit Wizard provides you with all the tools necessary to produce an electronics project from start to finish – even including on-screen testing of the PCB prior to construction!

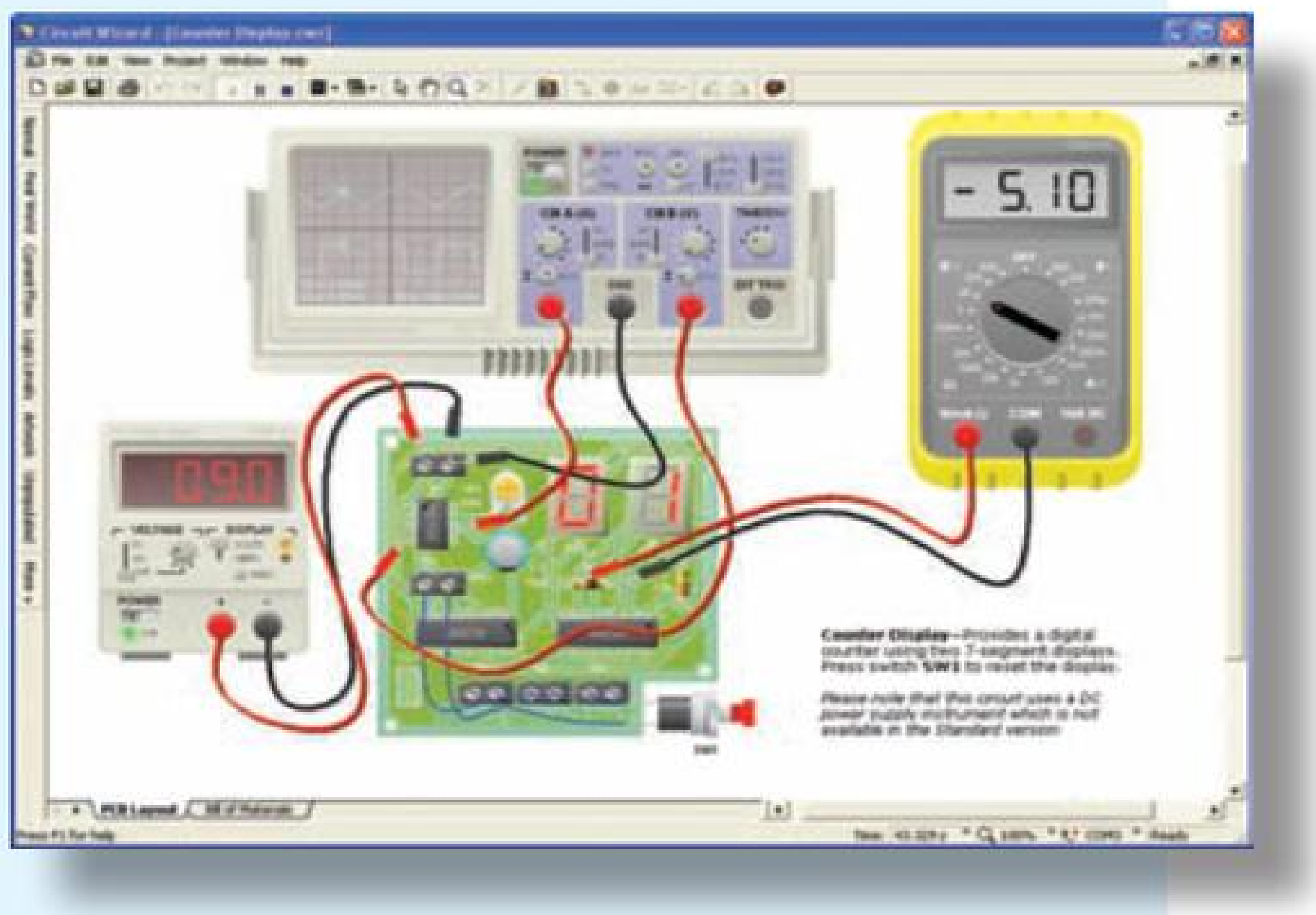
Circuit Wizard is a revolutionary new software system that combines circuit design, PCB design, simulation and CAD/CAM manufacture in one complete package.

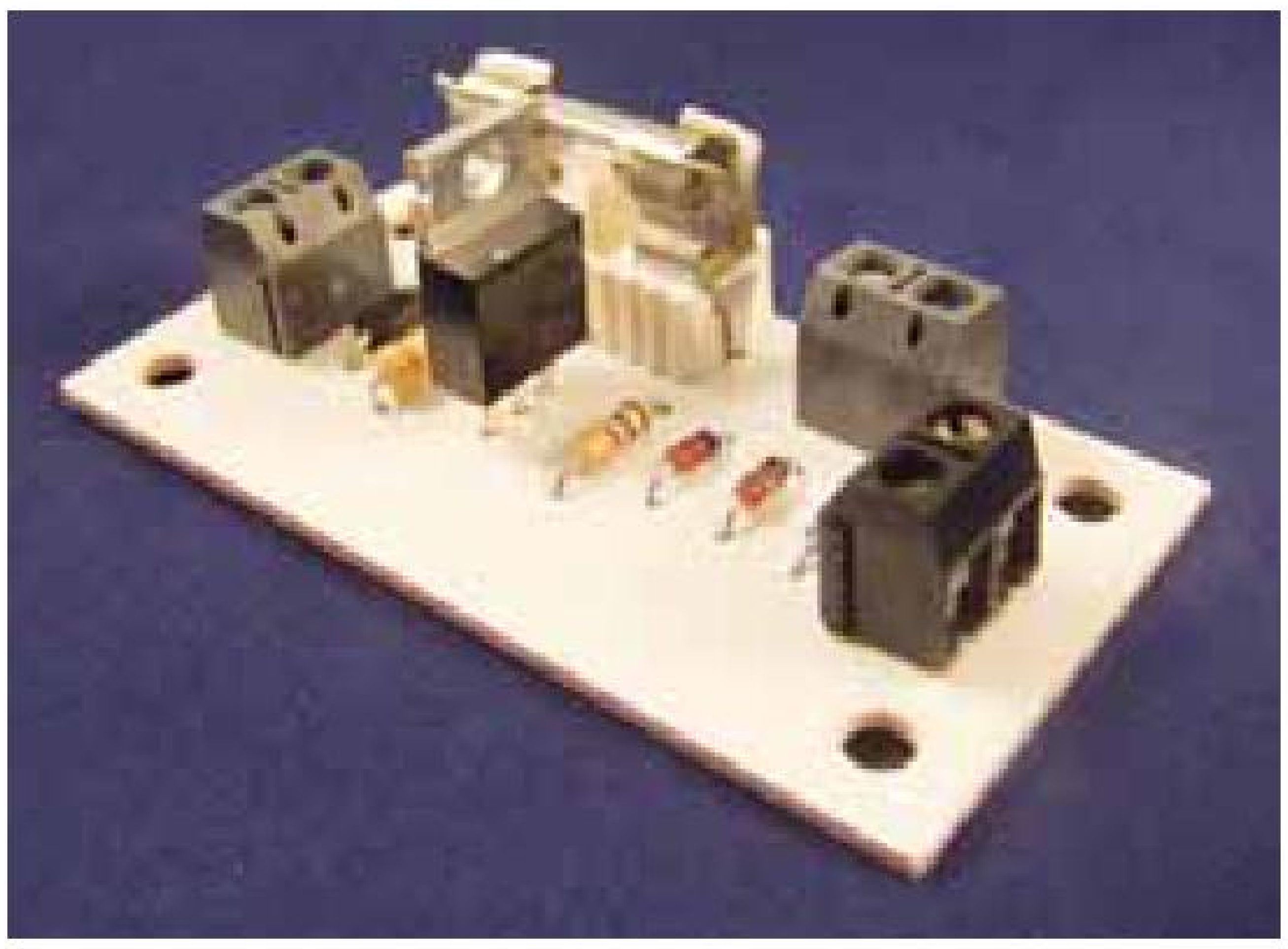
Order direct from us on 01202 880299

- *Circuit diagram design with component library (500 components Standard, 1500 components Professional)*
- *Virtual instruments (4 Standard, 7 Professional)*
- *On-screen animation*
- *Interactive circuit diagram simulation*
- *True analogue/digital simulation*
- *Simulation of component destruction*
- *PCB Layout*
- *Interactive PCB layout simulation*
- *Automatic PCB routing*
- *Gerber export*
- *Multi-level zoom (25% to 1000%)*
- *Multiple undo and redo*
- *Copy and paste to other software*
- *Multiple document support*

This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

Standard **£61.25** inc. VAT Professional **£91.90** inc. VAT





Completed Solar-Powered Charger circuit board

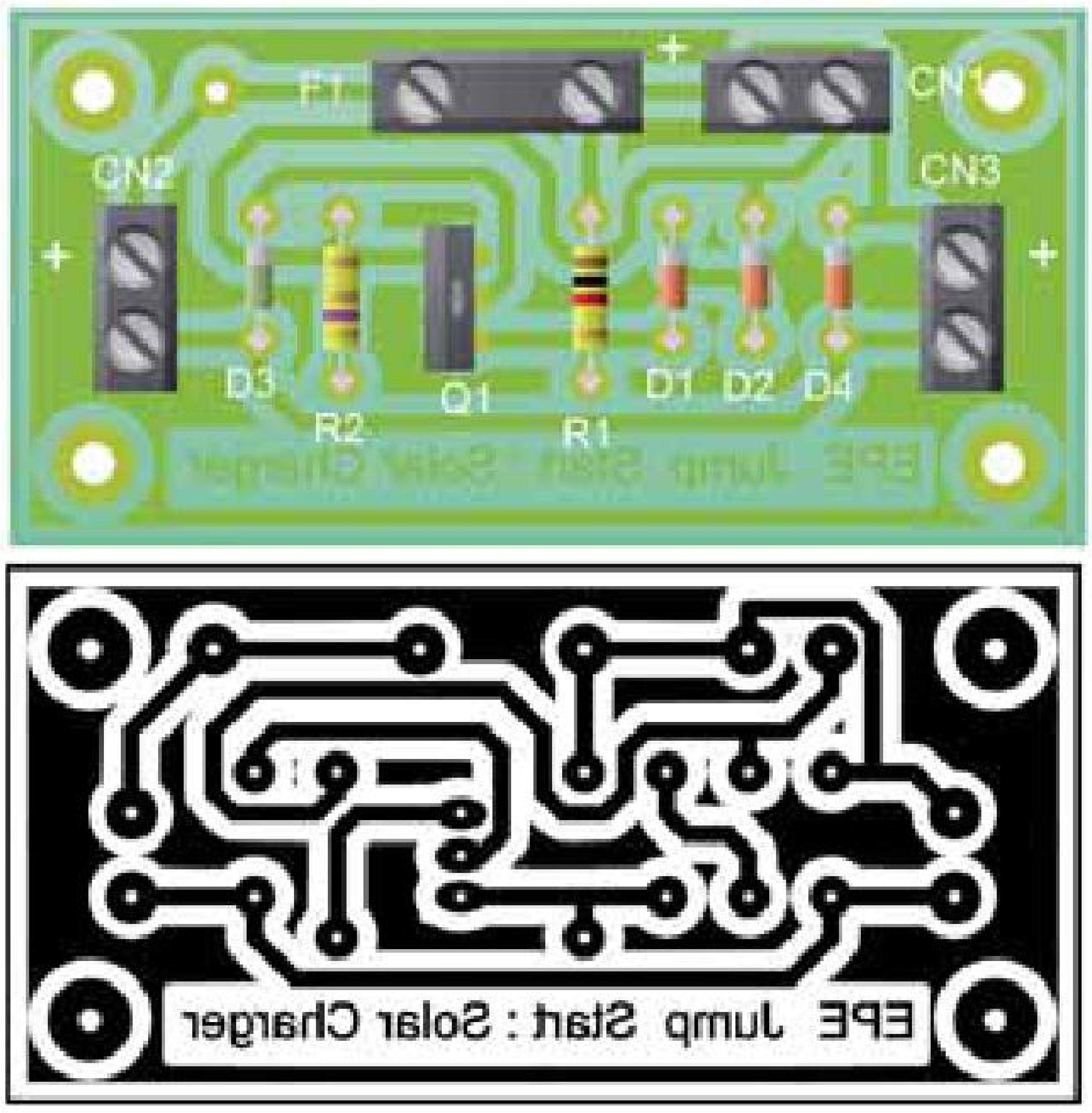

F1
CN1
CN2
CN3
+
D3
R2
Q1
R1
D1
D2
D4
EPE Jump Start : Solar Charger

Fig.8. PCB artwork showing real world and PCB views

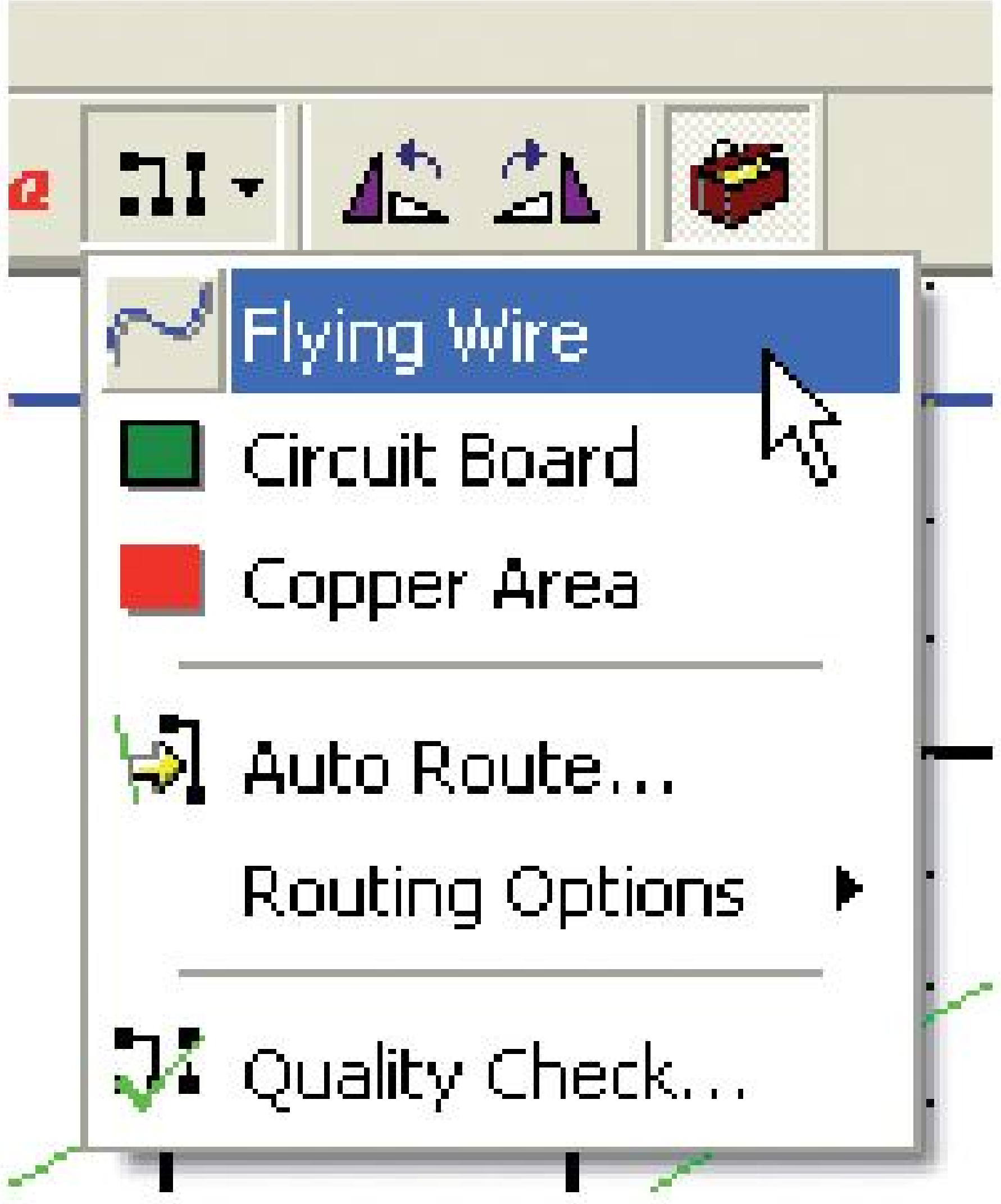

Flying Wire
Circuit Board
Copper Area
Auto Route...
Routing Options
Quality Check...

Fig.9 (left). Quality check toolbar

circuit to make sure that it matches up properly, as well as carrying out a number of checks on your design.

Enclosure and mounting arrangements

To get the best out of solar cells they need to be oriented to point directly at the sun. For this reason, we came up with a triangular case/stand, so that the cells will be mounted at an angle pointing up towards the sun. The reverse of the triangle shape also creates a neat ledge to support all of your gadgets, large enough to hold a phone, media player or small tablet.

We used coloured 5mm frosted acrylic to manufacture the stand; laser cut to size and bent up using a line bender. Fig.10 shows our basic stand design with Fig.11(a) and Fig.11(b) showing the required bend angles and formed stand respectively. The design files for the stand are available to download in various formats from the author's website.

Care needs to be taken to get the angles just right, so that the base

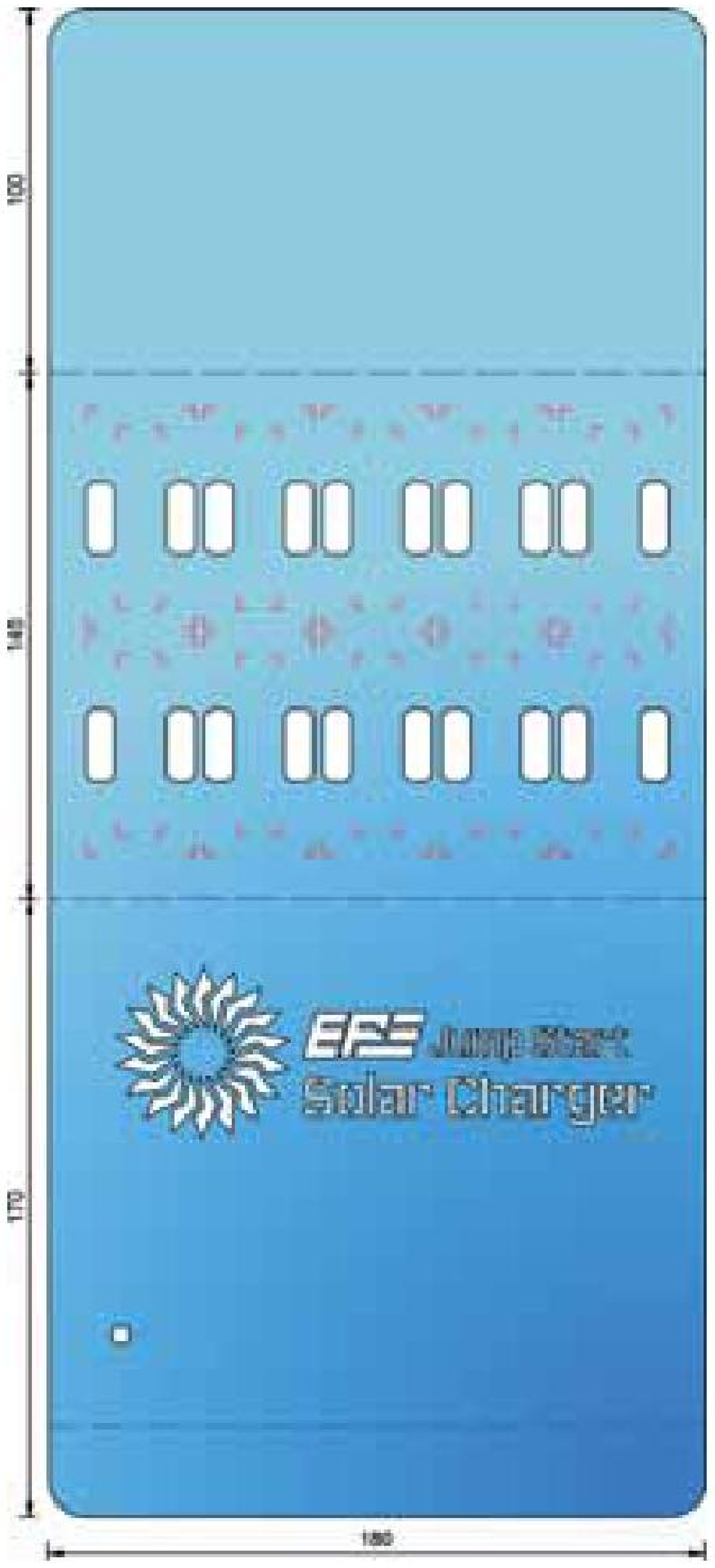
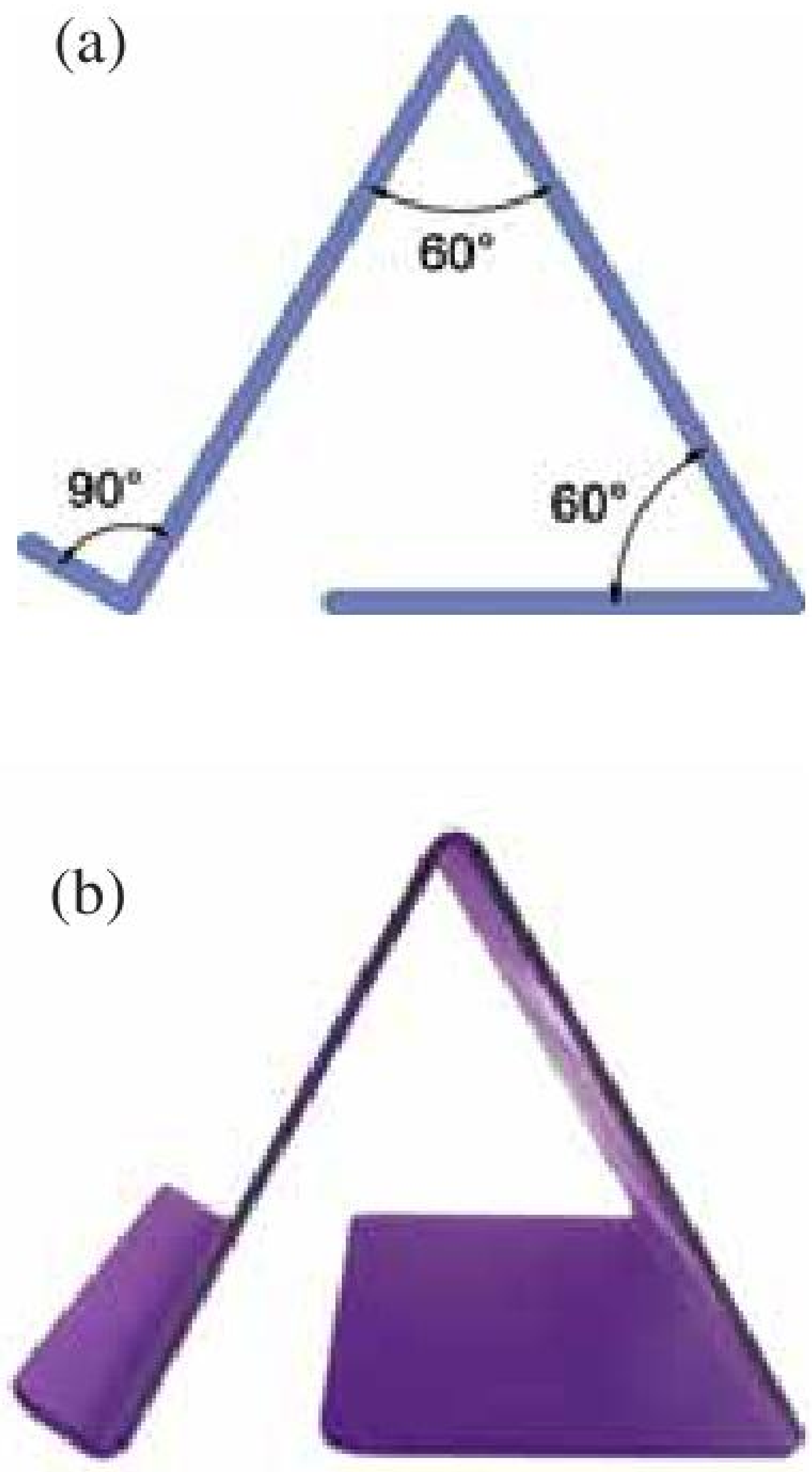

100
145
170
180
EPE Jump Start
Solar Charger

Fig.10 (left). The basic stand design (before folding into a prism shape)


(a)

(b)

Fig.11. Stand design: (a) folding diagram (b) the completed stand after folding (see note)

sits flat and the gadget stand meets the surface on which the unit sits. A 60° former was used to ensure that the angles were spot on.

As an alternative, a similar design could also be made with thin sheet metal or even using stiff cardboard (eg, mounting board) scored and folded to form a triangular prism shape. If you use sheet metal, some additional insulation will be required in order to prevent the connections on the rear of the solar cells from shorting to the metal stand.

Solar cells

Our solar-powered charger uses ten individual solar cells (Fig.12) connected in series. Small cutouts were made where the connections are positioned on the reverse of each solar cell to allow the wires to run through and sit flush. The solar panels were attached to the stand using double-sided tape, as shown in Fig.13 and Fig.14.

When cutting the plastic, we engraved corner marks to help us locate the cells and tape. Foam pads, velcro or adhesives could also be used for this purpose, although good quality double-sided tape is quick, clean and gives a neat flush finish, as well as allowing the possibility of removing the cells at a later date.

Wiring up

We recommend pre-wiring the solar cells with short lengths of wire before attaching them to the stand (Fig.15), as trying to solder them through the holes in the stand once in place could be a little tricky. We also recommend placing them so that their connections are positive-negative-positive-negative, so that they can be 'daisy chained' together on the reverse.

The PCB was attached to the internal horizontal shelf using plastic PCB posts and the careful application of super-glue. The battery pack, containing the four NiMH batteries, was attached using a short strip of sticky-backed velcro, so that it can be easily removed/replaced. Fig.16 shows the mounting arrangement for the internal battery holder and PCB.

Making a connection

Depending on the equipment that you'd like to charge you may want to attach different types of connector. Discount shops and market stalls are a good source of cheap charger/USB leads that can be cut down and connected to the circuit. Make sure that you check the appropriate connections for the connector/device; pinouts are easily obtained from the Internet in most cases.

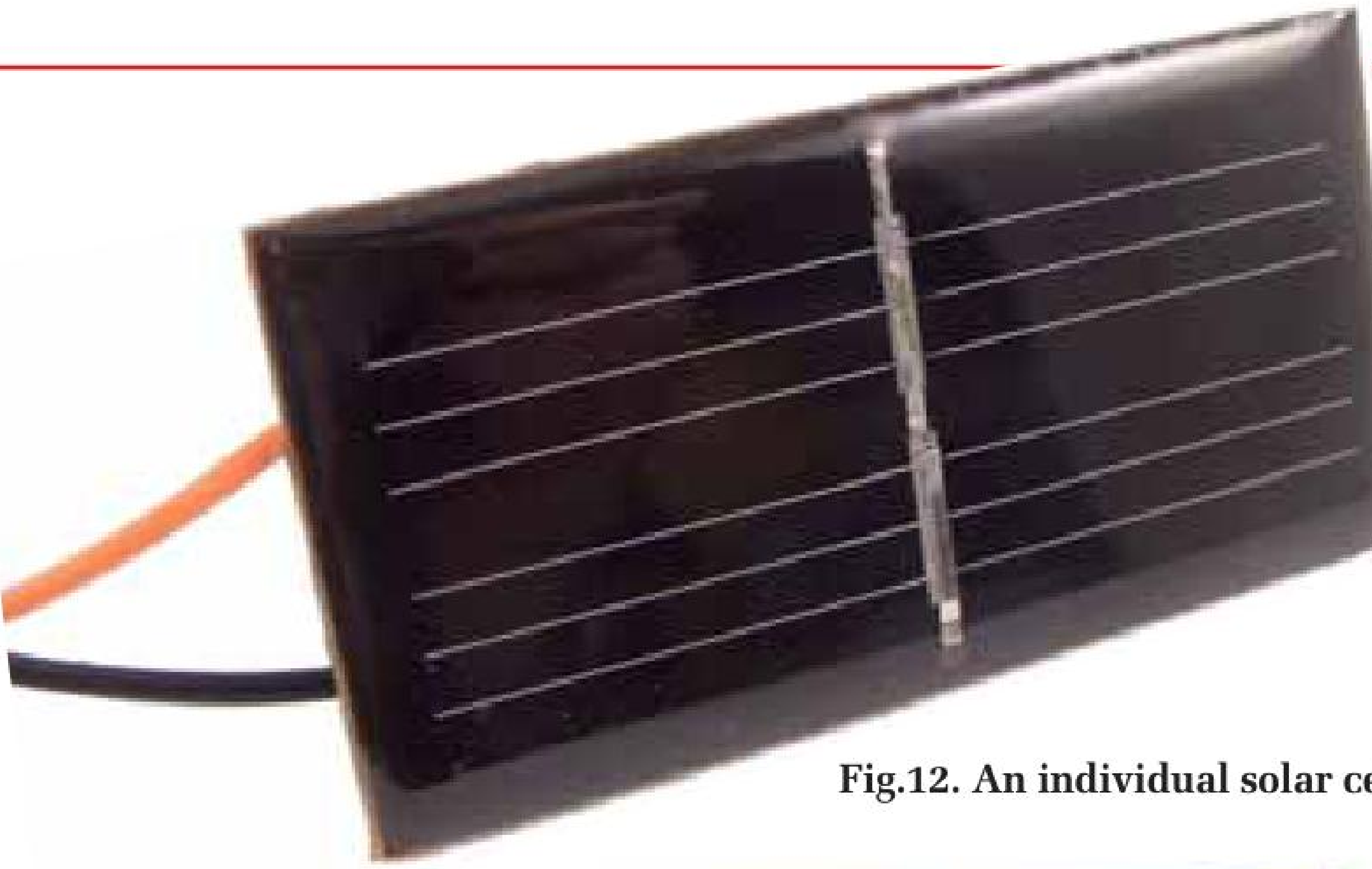


Fig.12. An individual solar cell

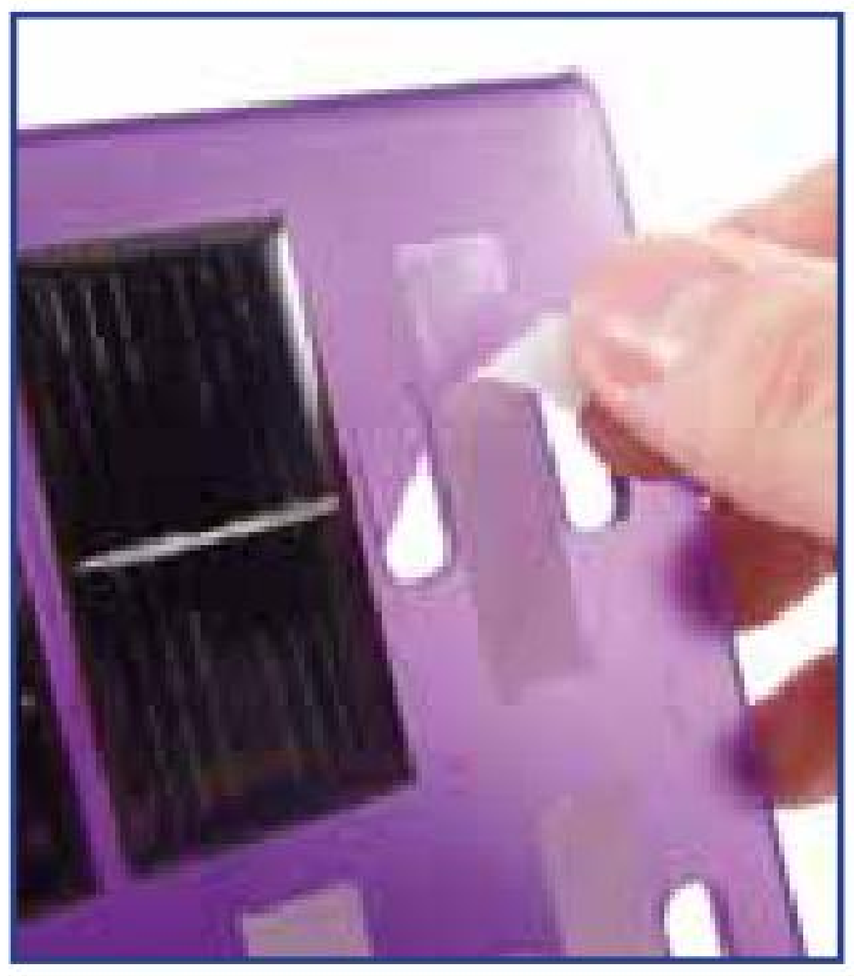


Fig.13. Solar cell mounting using double-sided tape

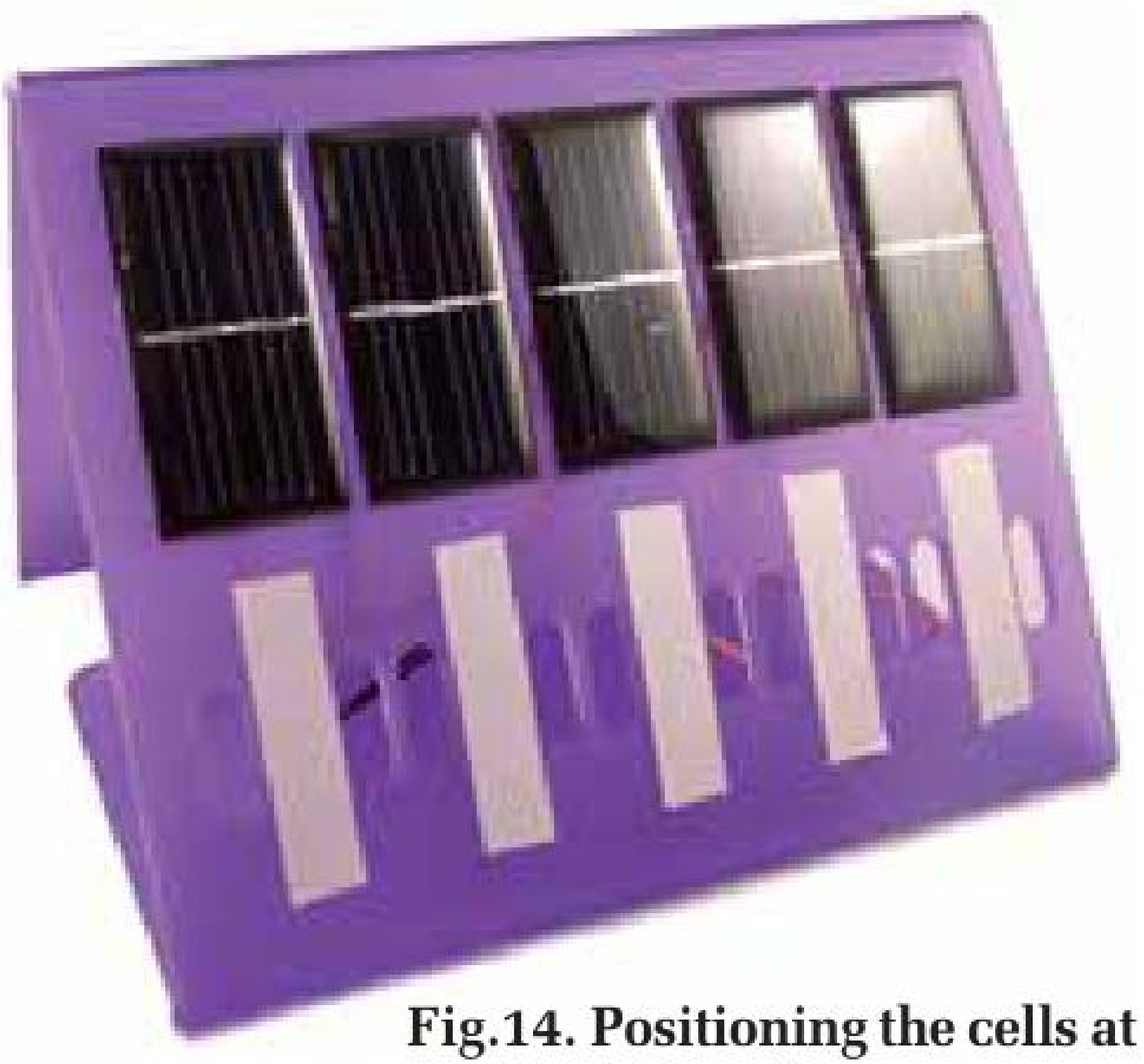


Fig.14. Positioning the cells at regular intervals

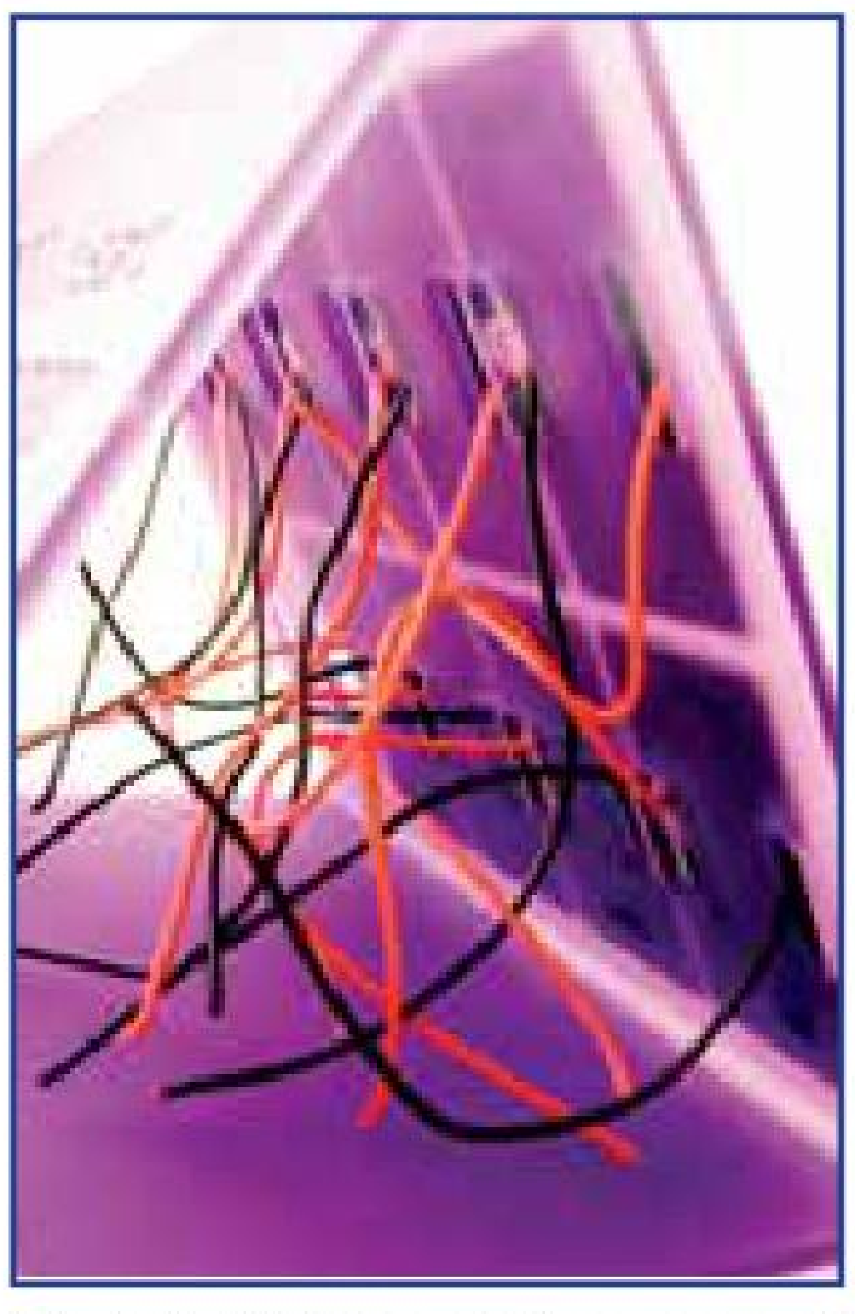


Fig.15. Wiring at the rear of the solar cell array

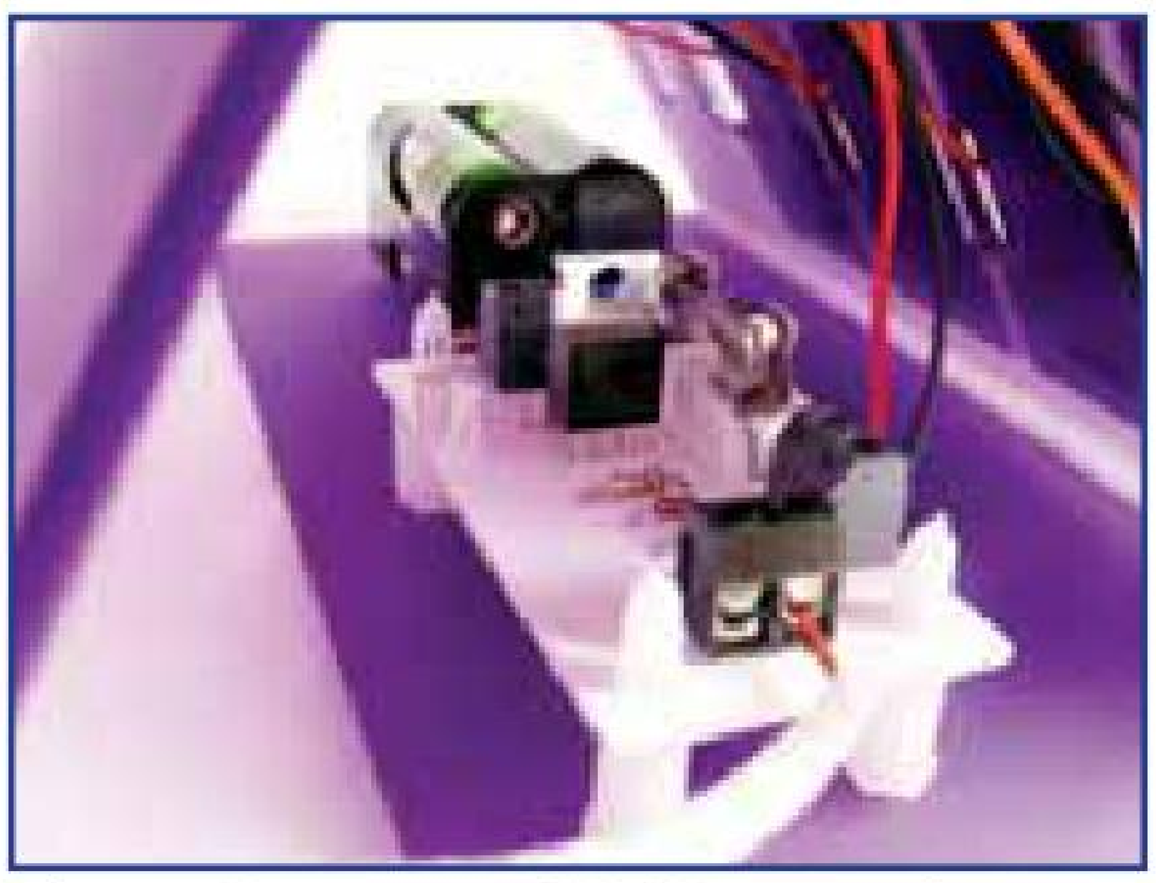


Fig.16. Battery and PCB mounting arrangement inside the prism enclosure

For more info:
www.tooley.co.uk/epe

A good option is to use the lead from a universal charger (Fig.17) so that many different types of phones/gadgets can be connected. Another option is to attach a female USB connector (Fig.18) – ours was taken from a cheap USB extension lead. In this way you can use the USB lead supplied with your device to connect it to the charger.

Note that some devices are designed only to operate with their own proprietary charger accessories, and therefore, you may need to modify the charger circuit and/or connections accordingly for your device. For

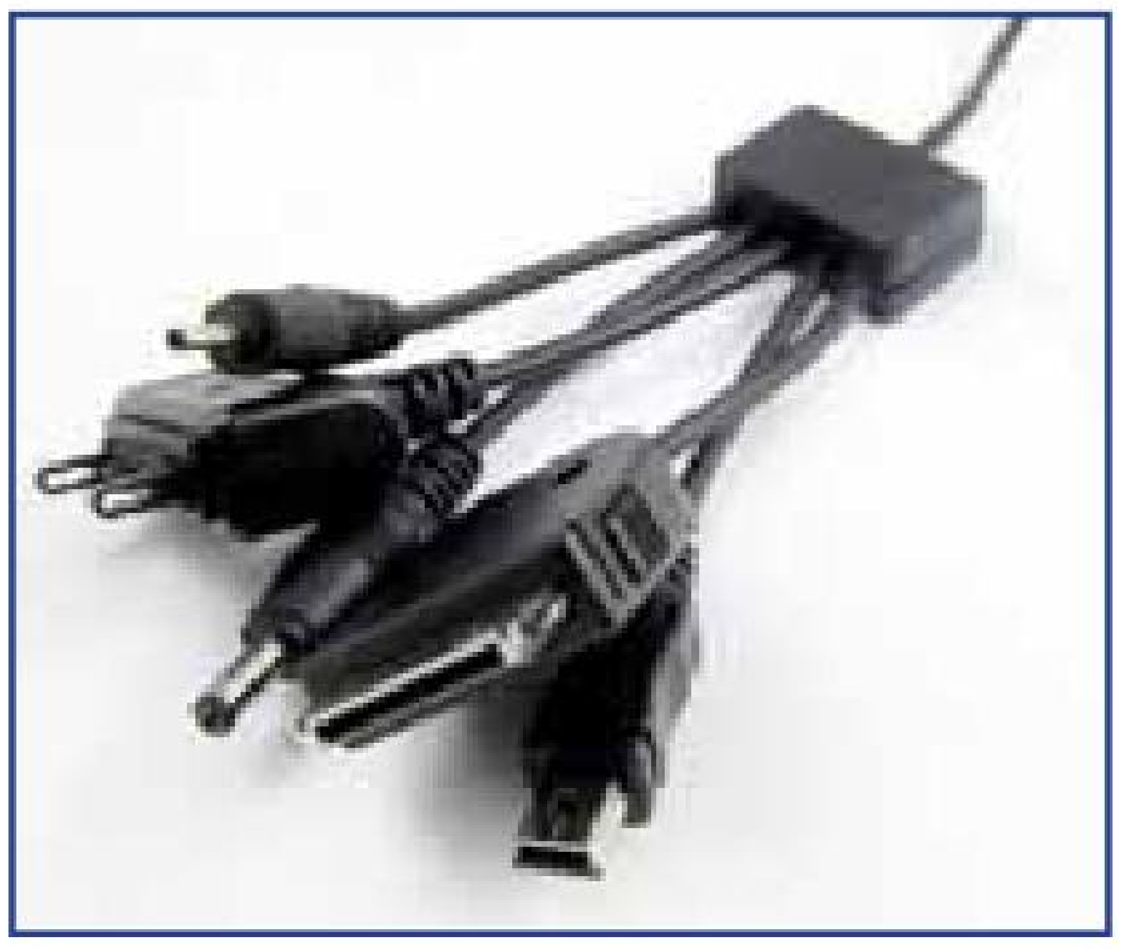


Fig.17. Flying lead with multiple connectors

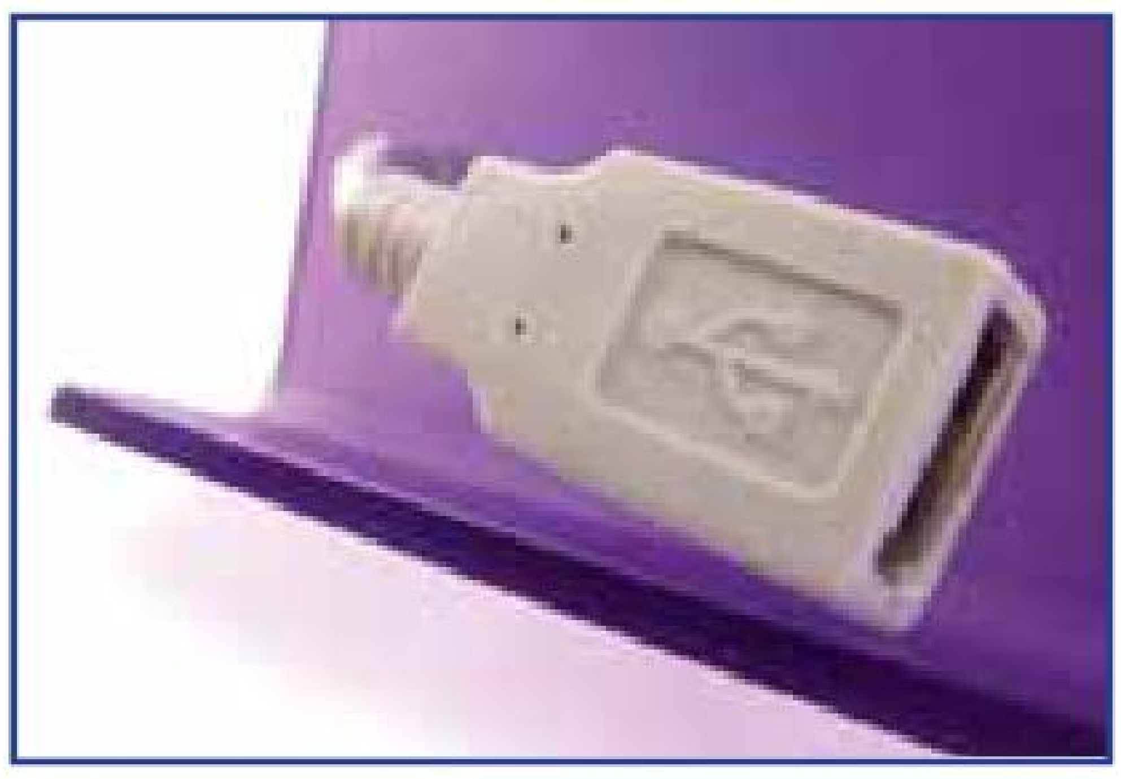


Fig.18. Female USB socket on a flying lead

example, the latest iPhones require additional specific voltages to be present on the USB 'data pins' to identify that a charger is present and permit charging.

Next month – we will be developing a versatile alarm unit that will help you protect your valuable possessions from theft.

Please take note

Please note that we cannot guarantee that the *Solar Powered Charger* will operate with any particular item of portable equipment. However, the prototype has been successfully tested with various current mobile phones, MP3 and multimedia players. Finally, here are a few helpful practical hints that will help you get the best out of the unit:

1. It is important to ensure that the four NiMH cells are fully charged prior to fitting to the solar charger. You might also find it useful to remove and recharge the batteries from time to time, particularly if the unit has not been used for some time.

2. There is no need to use expensive high-capacity NiMH batteries. Good quality batteries rated at 800mAh to 1200mAh should be adequate for operation, as long as they are kept topped-up by regularly placing the *Solar Powered Charger* in full sunlight.

3. Some mobile phones and other equipment have in-built 'intelligent' charging circuits. These work by sensing the capacity of a charging device and rejecting those that they don't like! This can sometimes reduce the ability of the solar charger to start charging under cloudy conditions, or at night. Placing the unit in full-sunlight (or under strong artificial light) will usually solve this problem.

4. Charging rates of portable equipment fitted with lithium ion batteries can often vary between about 100mA and 500mA, and a full charge may require a connection time of several hours, depending upon the equipment to which the *Solar-Powered Charger* is connected.

5. Remember, in the UK the level and duration of sunlight can often be extremely variable. In particular, do not expect the charge in the internal NiMH battery to be replenished very quickly. Several days of sunshine may be required to completely charge a battery.

When fully charged, it is easy to keep the internal battery 'topped up' by simply placing the charger in a sunny spot ready for use!

As mentioned above, some modern electronic gadgets can be quite fussy about their power sources, and can also be damaged by excessive or incorrect parameters. Therefore, before putting the *Solar Powered Charger* into service, we strongly recommend that you carefully check the specific requirements of the equipment that it is to be used with.

Photo gallery...

The Gallery is intended to show readers some of the techniques that they can put to use in the practical realisation of a design, such as PCB fabrication and laser cutting. This is very important in an educational context where learners are required to realise their own designs, ending up with a finished project that demonstrates their competence, skills and understanding. The techniques that we have used are available in nearly every secondary school and college in the country. We believe that our series will provide teachers with a tremendously useful resource!

Stand detail before forming

Bending stand using 60° former

Special thanks to Chichester College *for the use of their facilities when preparing the featured circuits.*

Raspberry Pi

What is the Raspberry Pi?

Mike Hibbett reports...

IN CASE you missed all the press coverage and media hype back in May this year, the Raspberry Pi is an extremely lost cost computer, designed by a small charitable foundation in Cambridge, UK. It's the brain child of Broadcom designer Eben Upton, who worked on the very processor used in the Pi – the Broadcom BCM2835.

The Pi was conceived to regenerate a fundamental interest in computing in children, in much the same way that the Sinclair Spectrum and the BBC Micro computer did in the 1980s. Eben had noticed that modern technology has removed the incentive for youngsters to program – what's the point, with all the high quality games and media readily available?

A retro Pi

The Pi provides a retro style return to the 1980s, but with a modern twist. Like its predecessors (the Acorn System 1 and the SCMP14 spring to mind) it's supplied as a raw PCB. But unlike those computers, or the modern equivalent Arduino platform, it provides an HDMI video output and a basic, but quite useable Linux operating system, with a graphical user interface based on the Debian distribution.

This is no microcontroller board; if you hook up a mouse, keyboard and WiFi dongle you can browse the Internet.

Value for your money

For a little over £25, you get the computer in its rawest form – a printed circuit board without keyboard, display or even a case, just like the Arduino microcontroller board. Unlike the Arduino, however, this is a very powerful computer, for its price – a 700MHz processor, 256MB of SDRAM, and a built-in graphics accelerator capable of rendering high definition video at 1080p through its built-in HDMI interface. All this at a price well below an Arduino Mega board!

The design is open source (with the exception of the graphics accelerator driver, for which only binary drivers are made available) and is capable of running the standard Linux operating system, without compromises. A strong on-line technical community has developed around the product, and specialised applications have already started to appear, such as ports of the media player XMBC.

Out of the box

For your £25 (or more accurately £36 from Farnell, £31 from RS Components) you get the PCB and nothing else, as shown in Fig.1. The software and instructions for use must be downloaded from the Raspberry Pi Foundation's website.

The computer is essentially a single IC, the Broadcom BCM2835, which integrates a CPU, HDMI video interface, graphics accelerator and a host of useful peripherals. 256MB of SDRAM is integrated into the CPU package. One other IC provides the wired Ethernet interface.

The standard interfaces include an HDMI monitor interface (obvious by now!), two USB interfaces (typically for mouse and keyboard, but can drive other devices), an Ethernet port and an SD card slot. The SD card is required to hold the operating system and user files, as there is no non-volatile memory on the board – the processor is configured to boot directly from SDMedia.

There are several versions (or 'distributions') of Linux available for the Pi, which we will come to shortly.

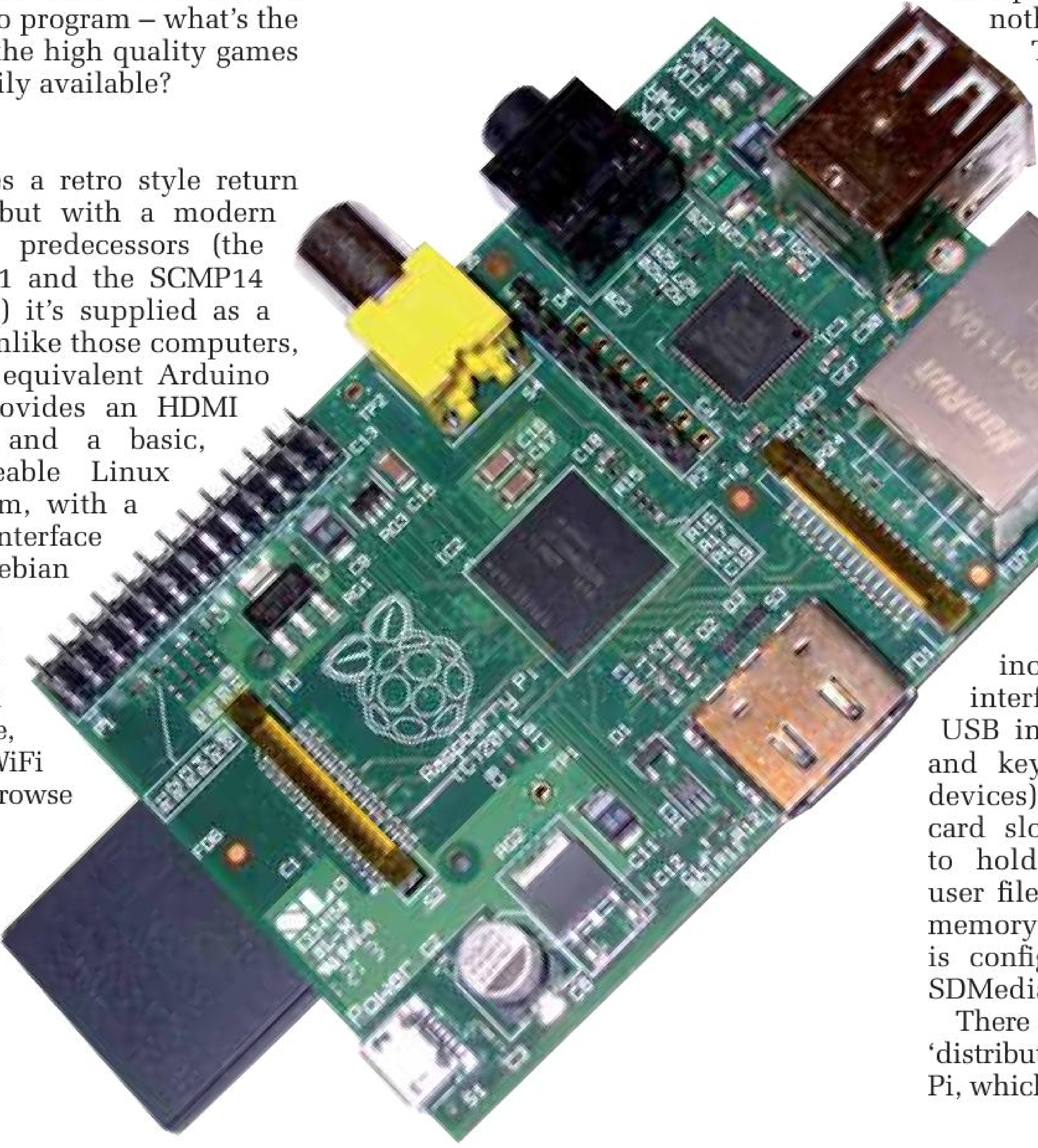


Fig.1. The Raspberry Pi printed circuit board (PCB)

Composite video and 3.5mm stereo audio output sockets are present for those who do not have access to an HDMI or DVI capable monitor or television. Power is supplied through a (power-only) micro USB socket. Although the audio output circuitry is present, there is no support for it in software yet. It is being worked on, however.

conceived to regenerate children's interest in computing

Two FPC connectors provide interfaces for a camera and a flat panel LCD, but software is not yet available for these either. FPC connectors mean that we can expect specialised cables and adaptors will be needed, which will not be cheap or hobbyist-friendly.

A 26-way 0.1-inch pitch DIL header provides 17 raw digital I/O ports, all available for use. Some of the pins are connected to hardware peripherals within the CPU, giving UART, SPI and I2C capability.

For the electronics hobbyist, this board would probably have been of little interest were it not for the easily accessible I/O interfaces made available, and perhaps the opportunity to learn about the use of Linux on small embedded systems.

What you need

As a minimum, you will need to supply a 2GB SDMedia card, USB mouse and keyboard. For power, 5V power supply with a mini-USB connector capable of delivering at least 1.2A, such as a smartphone charger. You will need an HDMI or DVI capable monitor and cable. A standard television with composite video input can be used. However, our experience with an older CRT television was not great when viewing text.

If you intend to connect to a network via wireless, you will need a powered USB hub and a supported USB Wi-Fi dongle. We had difficulty finding a supported wireless dongle, so if you are intending to purchase one you should be very careful to either select one that has already been tested, or find a willing supplier who will take it back if it doesn't work!

With all the cables and SDMedia card connected the board is somewhat fragile, and not really suited for unattended use by children – a little rough handling can easily break the card connector, and it is easy for stray USB cables to short the circuit.

Cases are now available through eBay from a number of sources, mainly laser cut perspex designs that are relatively cheap and look quite funky. We suggest the purchase of a case is a priority.

Software installation

The Linux operating system and a number of useful applications specially configured for the Pi have been bundled together into a single image file that can be transferred to an SDMedia card. The file can be found on the downloads page of the **raspberrypi.org** website.

For Windows users, an application called Win32DiskImager should be used to transfer the image to the card – do not simply copy it. This application is also available on the same webpage. Both are, of course, free of charge.

With the software installed on the SDMedia card, it was a simple job of (carefully) sliding the card into the precariously exposed socket, plugging in a USB hub, Wi-Fi dongle, keyboard, mouse, HDMI lead and powering up. The resulting jumble of wires around the PCB can be seen in Fig.2, emphasising the need for a case.

There is no power switch – in fact, no buttons or jumpers at all – and with power applied the display came quickly to life, displaying a long stream of text, indicating the progress of the operating system start-up.

After a few tens of seconds, a login prompt appears, at which point you must enter the default username and password. Doing so leaves you at a shell prompt similar to DOS.

You must enter a single cryptic command to start the graphical user interface:

```
sudo startx
```

After a few more seconds, you are presented with a fairly familiar user interface display, somewhat similar to Windows XP, with a series of menus available by clicking an icon in the bottom left of the display.

At this point, the limitations of the system become apparent. There is a noticeable delay between clicking on a menu option and a sub menu appearing; it can take over ten seconds for an application to start. These delays are hardly surprising for a machine with just 256MB of RAM and an SDMedia card for storage, but it still takes some getting used to.

Pi provides a retro 80s style with a modern twist

There are dozens of applications installed, but as this is targeted at school children we thought we would start with the 'Educational' section. The first application we came across was called **Scratch**, a graphical programming language for creating interactive stories and games. Never having come across this before, we headed off to another PC to look it up on the Internet. Ten minutes later when we returned, our youngest daughter had already created an animated story, as shown in the title picture. 'We use Scratch at school' came the explanation.

For more serious programming, the Pi Foundation is recommending the Python programming language,

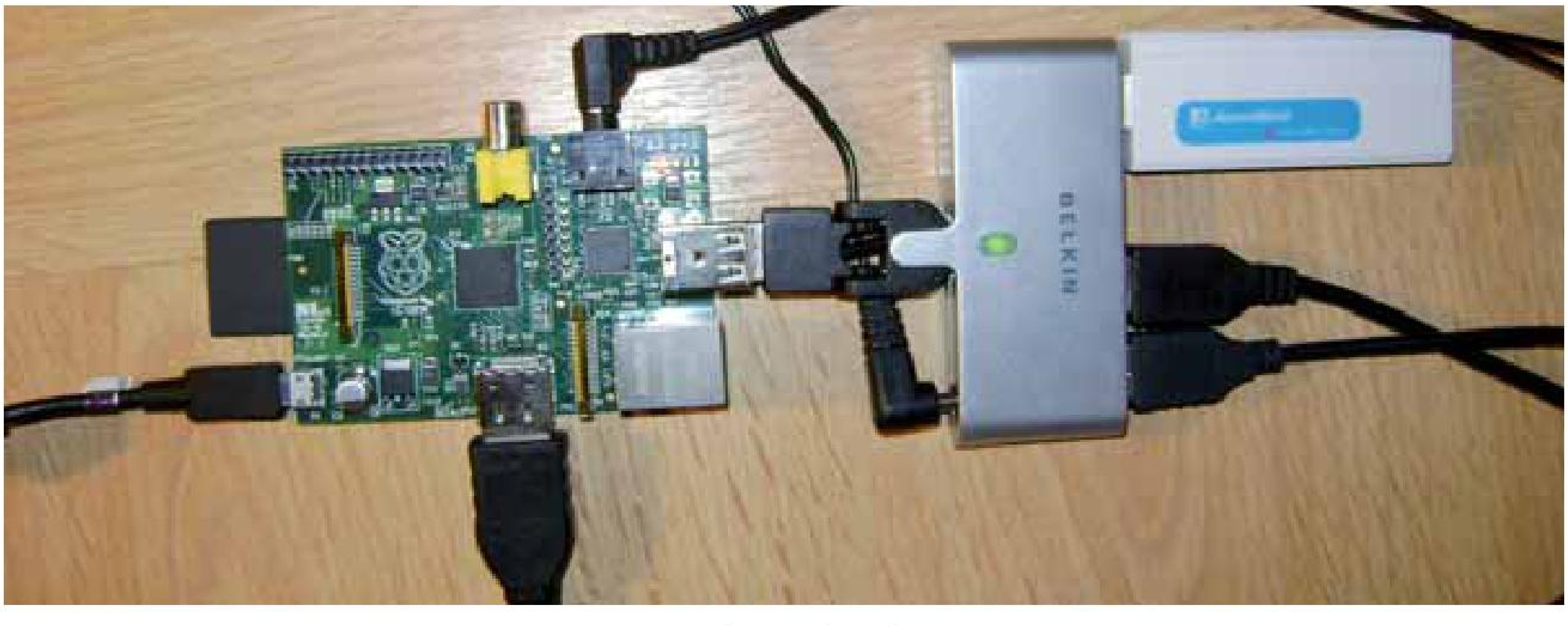


Fig.2. Wired up and ready to go

and included in the image is a great development environment for building Python applications called SPE. Our attempt to interest our ten year old in writing Python programs floundered at this point, as she had discovered the web browser (Fig.3) and had gone off in search of online games. Ah well, it wasn't a school night!

> ***For a little over £25, you can get the Pi computer in its rawest form...***

As an experiment, we left the machine with one child for a few days without any instructions, other than how to log in. Although the lack of word processing software or printer access caused some annoyance, after just a few days it was being used to record homework timetables and notes. The machine clearly had some appeal, and this has encouraged us to start exploring computer programming with the children in a more structured manner.

What next?

Six months ago, the most common question from the community of interested Pi hobbyists was: 'When am I going to get my Pi?' Now, the question is: 'What am I going to use it for?'

For us electronics hobbyists, we are, of course, interested in what we can connect it up to, and how we can make use of these new and more powerful features. This isn't about making our current pet project smaller or run faster, this is about creating projects that were previously unthinkable.

Fig.3. Python programming IDE and Midori web browser running concurrently

Here, to whet your appetite, are a few of the ideas that have been circulating round the *EPE Chat Zone* forum on the Internet:

Internet Radio – With a Wi-Fi dongle, speaker, small LCD and a few buttons a compact battery-powered Internet Radio receiver could be constructed. Great for tuning into those obscure broadcasts that are not available from normal analogue or DAB stations.

Home Media Centre – Similar to the Apple TV box or Tivio, a cheap and silent means of storing and playing back digital videos and photographs on your television.

WIB mark 2 – a fully functioning personal webserver that you can connect to your home router.

And of course, a cheap low power PC for the children.

Back to the future

Over the coming months, we will explore some of these ideas and develop a few more. Our first project, however, will be to address one of the Pi's omissions – the lack of a battery-backed real-time clock.

We will also be looking at how software can be created for the Pi (both natively and cross-compiling on a Windows PC) and exploring the Linux operating system in general. ***EPE***

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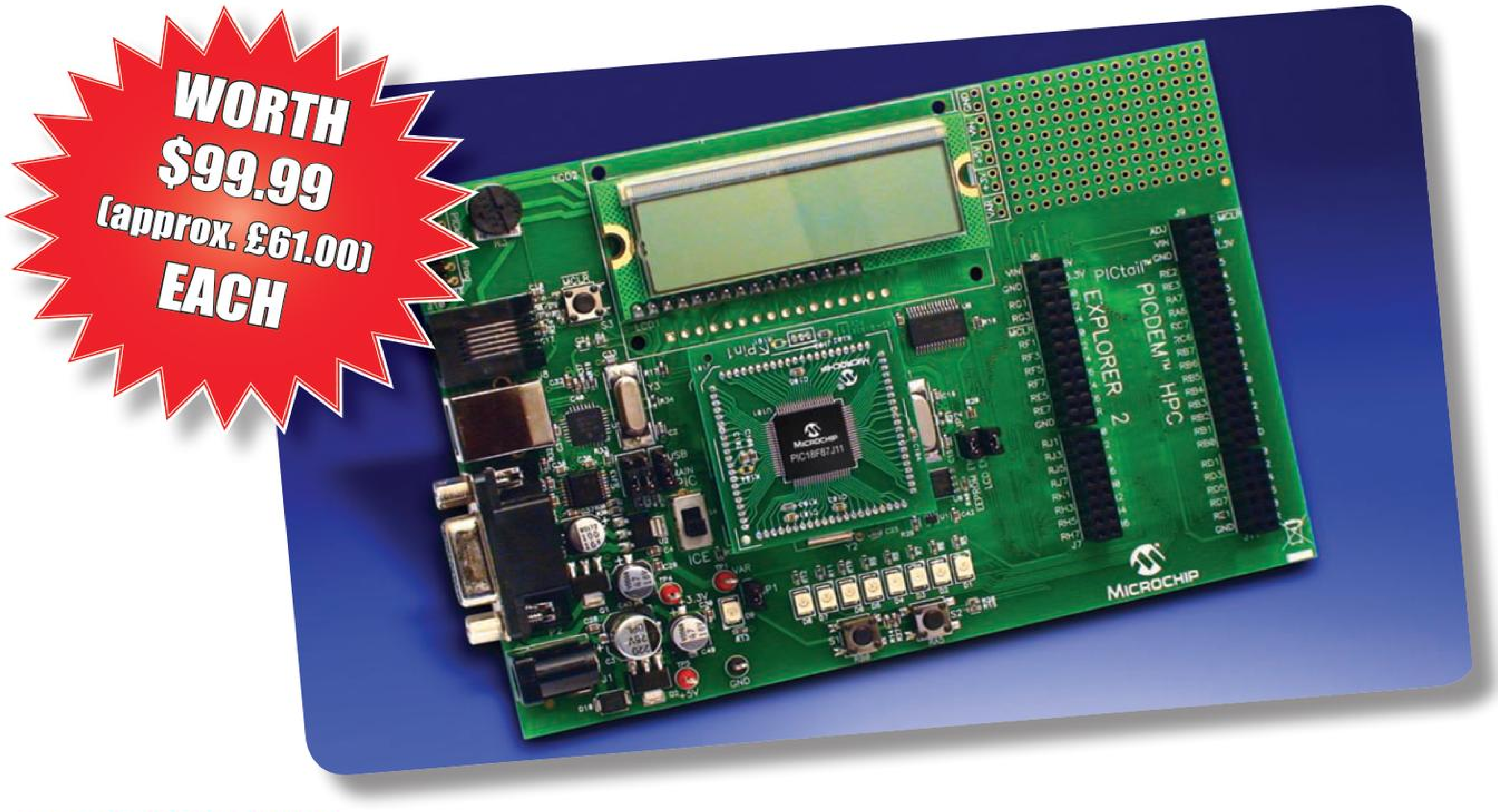

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PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

Completing the Uno32 Video Driver

We left off last month with a basic working video driver for the ChipKIT Uno32 board. The code was a little raw – it wasn't well documented or provided an easy-to-use interface, nor was it created as a library. We sort these points out this month, as we complete our series on the ChipKIT PIC32 Arduino boards.

First, a little more detail on the inner workings of our driver code.

Video internals

We explained last month how a line of pixels is displayed by pushing the ones and zeros out through the SPI module, clocked at the pixel clock rate of the display. This is handled by the function **fillBuff** in the main driver source file **vidgen_drv.cpp**.

As the SPI module must output a complete line of pixels, without any delays between any two pixels, we must create a buffer for the entire line of pixels and feed these to the SPI module through a high priority interrupt. Two line buffers are used, an active one from which the SPI interrupt reads data and an in-active buffer that can be filled while the other is being read. When the SPI interrupt completes a full line of pixels it automatically switches to the other buffer, 'ping-ponging' between the two.

Due to memory constraints in the PIC processor we have chosen to display only text characters, but these still have to be stored somewhere, so we define an array of characters in RAM called **textBuffer** to do this. Each entry in the array defines the character to be displayed at a particular location on the screen. The actual pixels to use for each character are stored in a fixed-value font table within the file **lcd_font.h**. The font is six pixels by eight pixels high. Only the first 128 characters are defined, leaving the remaining 128 for future definition.

The fillBuff function converts the textBuffer contents to pixels by looking up each character in turn within the font table, and taking a six-bit wide 'slice' of the appropriate font entry and inserting it into the in-active pixel line buffer. The SPI module is configured to transmit 32-bit words, and unfortunately six does not go into 32 very well – hence the rather strange looking code in the fillBuff routine.

This has been optimised to be as fast as possible because this is the most time-critical routine, having to complete the creation of the next buffer of 480 pixels within 26μs, while still leaving time for our main application to run!

The scanning of the text buffer, conversion of the characters to pixel data, and the rendering of that data out to the display through the SPI port are all done through interrupts; the user's application has no awareness of this activity other than a reduction in the apparent speed of the processor (although timer modules will still count at the same rate.)

Our next step is to define a set of routines that can be called by the user's application to populate the text buffer and enable the driver. The first obvious function is the driver setup routine, which will prepare the various variables, buffers and interrupt features. We have called this **vidgen_setup**.

Driver API

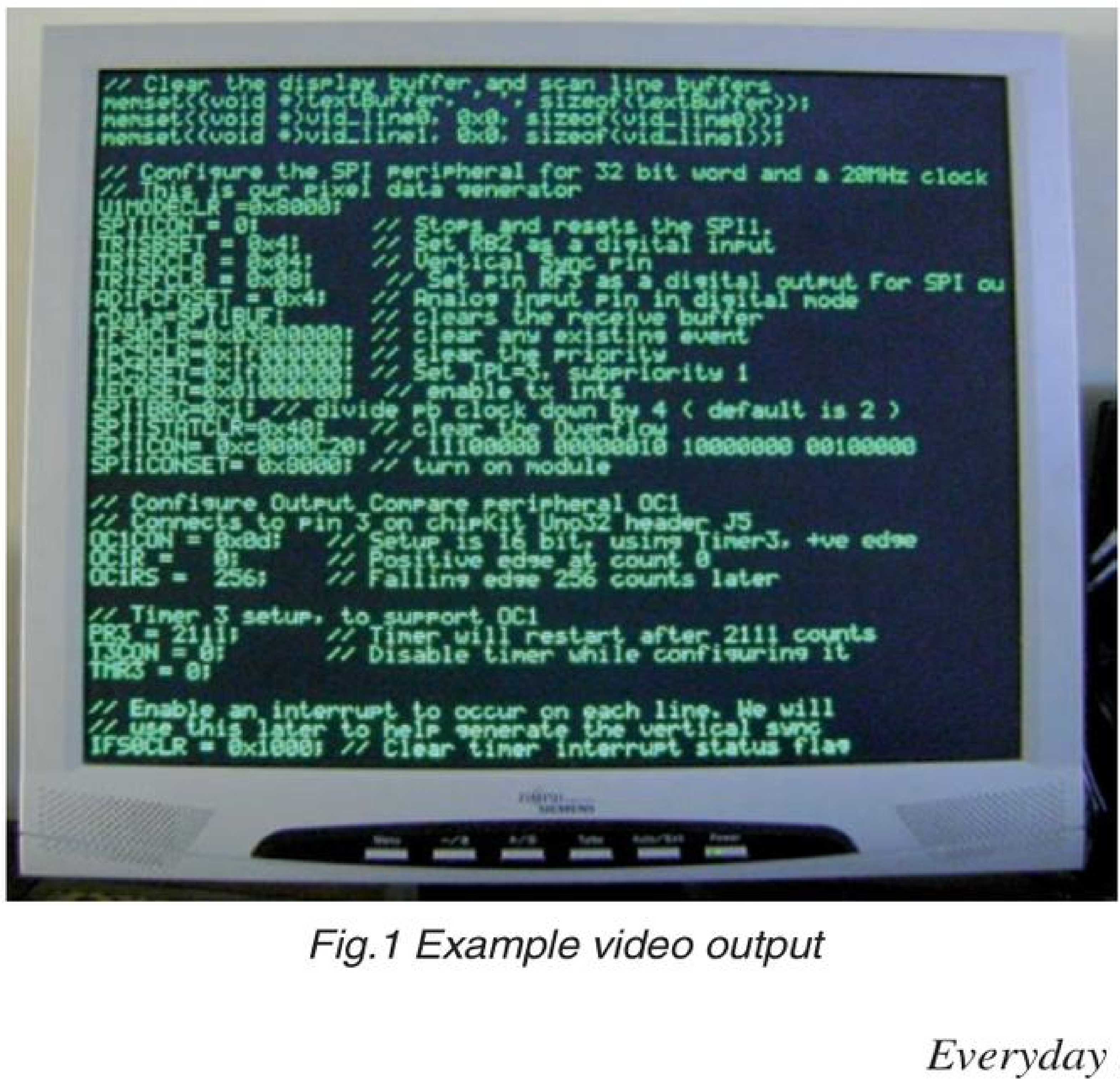
Next, what functions will we want to supply to the user? It's possible to get carried away at this point, so we restrict ourselves to the basics – write a character to the display buffer (**vidgen_putc**), read a character from the display buffer (**vidgen_getc**), write a string to the display buffer (**vidgen_puts**) and a simple 'clear-screen' routine **vidgen_cls**. The read and write routines all include an x and y coordinate parameter to locate where on the 'screen' the character will be placed.

When writing strings, there is no concept of a 'current cursor position' – this kind of logic can be built on top of the library functions provided. The key point is that all further enhancements can be done without any knowledge of the underlying driver design, nor an understanding of how the video driver works. We have effectively 'abstracted away' the details.

While significantly simplifying the task of using the driver code, it also means that the driver could be completely rewritten (perhaps in assembly language, or for a different video interface) without affecting the user application. Collected together, these functions form the application programming interface (API) to the driver.

By now, you have probably noticed that all functions and constants defined in the header file **vidgen_drv.h** start with the word 'vidgen'. While this may appear a waste of typing, it's an important addition – it ensures that our functions do not clash with any functions defined elsewhere, such as in the standard C library or any other user-defined library.

This is considered good programming style, and as these functions form the lowest layer of the interface to the driver code, it's likely that they will be wrapped in your own routines, so what they are called should not cause any problems.



```
// Clear the display buffer and scan line buffers
memset((void *)textBuffer, ' ', sizeof(textBuffer));
memset((void *)vid_line0, 0x0, sizeof(vid_line0));
memset((void *)vid_line1, 0x0, sizeof(vid_line1));

// Configure the SPI peripheral for 32 bit word and a 20MHz clock
// This is our pixel data generator
U1MODECLR =0x8000;
SPI1CON = 0;              // Stops and resets the SPI1.
TRISBSET = 0x4;           // Set RB2 as a digital input
TRISDCLR = 0x04;          // Vertical Sync pin
TRISFCLR = 0x08;          //  Set pin RF3 as a digital output for SPI ou
AD1PCFGSET = 0x4;         // Analog input pin in digital mode
rData=SPI1BUF;            // clears the receive buffer
IFS0CLR=0x03800000;       // clear any existing event
IPC5CLR=0x1f000000;       // clear the priority
IPC5SET=[illegible];       // Set IPL=3, subpriority 1
IEC0SET=0x01000000;       //  enable tx ints
SPI1BRG=0x1; // divide pb clock down by 4 ( default is 2 )
SPI1STATCLR=0x40;         // clear the Overflow
SPI1CON= 0xc0000C20;  //  11100000 00000010 10000000 00100000
SPI1CONSET= 0x8000;  // turn on module

// Configure Output Compare peripheral OC1
// Connects to pin 3 on chipKit Uno32 header J5
OC1CON = 0x0d;       // Setup is 16 bit, using Timer3, +ve edge
OC1R =   0;          // Positive edge at count 0
OC1RS =  256;        // Falling edge 256 counts later

// Timer 3 setup, to support OC1
PR3 = 2111;          // Timer will restart after 2111 counts
T3CON = 0;           // Disable timer while configuring it
TMR3 = 0;

// Enable an interrupt to occur on each line. We will
// use this later to help generate the vertical sync
IFS0CLR = 0x1000; // Clear timer interrupt status flag
```

Fig.1 Example video output

Library conversion

Libraries in the Arduino world are very different to what C or Assembly language practitioners are familiar with. Here, libraries are simply directories containing source code, a standard set of which are distributed with the IDE and installed automatically. You can find them in the directory hardware\pic32\libraries\ in the installation directory of MPIDE.

Each sub-directory contains the .cpp file (or files), a single .h header file and an optional text file called **keywords.txt**. The latter is used to list the function names of the API and associate them with a tag indicating their type – KEYWORD2 for function and global variable names, and LITERAL1 for any constants. The **keyswords.txt** file is scanned by MPIDE on startup to enable the editor to highlight these reserved words, a nice touch.

To include our video driver as a library within MPIDE, simply create a new sub-directory called **vidgen** and copy in the files from the zip file linked to this month's article on the *EPE* website. The next time you start MPIDE, the library will be automatically detected, which you can confirm by creating a new sketch and clicking Sketch->Import Library.

When you select the vidgen library, all that happens is that a reference to the header file is added to your Sketch. You do not need to do anything else, such as copy files over to your Sketch; MPIDE will simply include the text found in the driver directory when it compiles your code.

An example sketch can be found in the **examples** sub-directory of the vidgen library. This displays, somewhat self-referentially, part of the driver source code. An example of the output on an LCD monitor can be seen in Fig.1.

If you want to share your own libraries with others then simply zip up the source code and send it to them. Once they copy the files to their installation directory the code is ready to use.

Next month

This wraps up our initial look at the chipKIT range of boards. Next month, we move back to MPLAB and return to basics for a while, covering a beginners view of assembly language programming – a subject we haven't touched on for quite a while! We look in particular at the differences between relocatable and absolute programming approaches.

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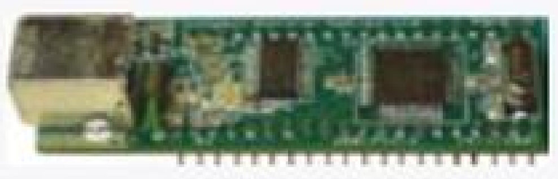

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CIRCUIT SURGERY

REGULAR CLINIC

BY IAN BELL

Damn fast buffers

FOR the last couple of months, we have addressed some of the issues raised by a set of questions about output buffer amplifiers posted on *EPE's Chat Zone* by **atferrari**.

I am about to build an output stage for a sine generator. I ran across several circuits of AB class amplifiers, but in spite of lot of reading, I still have many basic doubts. My questions are:

1) A buffer output is expected to have gain by itself? In other words, what defines the gain in a push-pull configuration?

2) Several function generators seem to set their output impedance just by using a series resistor of 50Ω/75Ω/600Ω at the output. Is that all that is needed?

3) Instead of building an AB stage, the LH0033 (or similar buffer), would be a better (if expensive) solution?

4) When reading about AB amps, it seems that those specifically for audio and those used as an output stage of signal generators share different necessities. Besides the obvious low impedance loads in audio, is there anything else that makes them so different?

5) Walter Jung in his IC Op-amp Cookbook *describes a circuit that has an output impedance of 10Ω [this has a class AB amplifier, and an op amp in a feedback loop]. What determines that value? How could I change it, if possible?*

6) I read somewhere in a forum that diodes [used for biasing] are old use; that a V_{be} multiplier should be used instead. Can anyone elaborate?

Gracias for any help to understand this a little more.

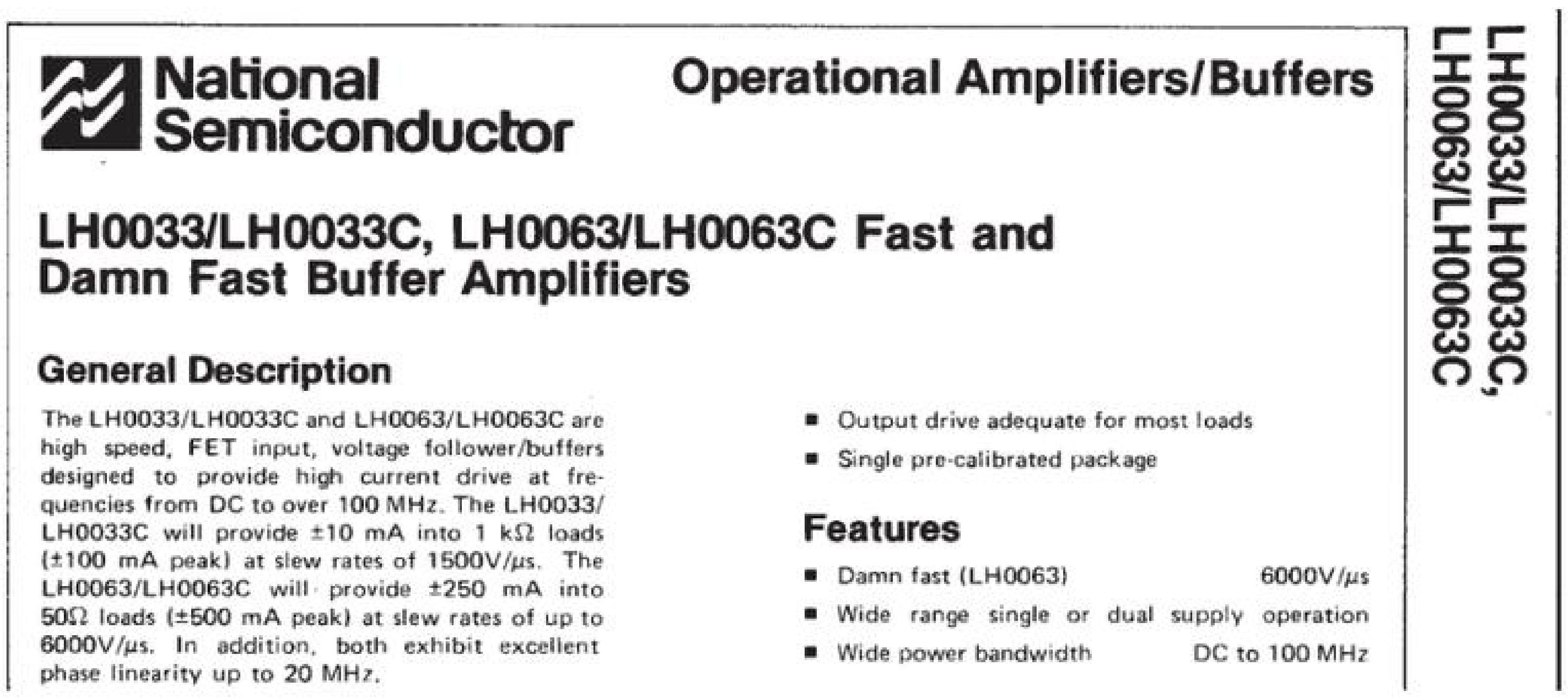
Damn fast buffers

An output buffer is a circuit which sits between a signal processing or generating circuit and the load, and provides the characteristics necessary to drive the load correctly. So far, we have looked at the basic principles of buffers and the general concept of output impedance. We have also looked at typical circuit structures used in these circuits.

This month, we will focus on question 3 and consider commercial buffers which fulfil this function. As atferrari mentions the LH0033, we will concentrate on circuits of this general type.

The LH0033 was a high speed, open-loop, JFET input voltage follower/buffer amplifier from National Semiconductor. This was a hybrid device, not a single IC. The LH0033 had a 10mA bidirectional output drive capability, at a slew rate of 1500V/μS (we will define and discuss slew rate later).

The related LH0063 could deliver even more – up to 250mA at 6000V/μS, although apparently they had a tendency to get very hot. In early datasheets, National Semiconductor described the LH0033 and LH0063 as 'Fast' and 'Damn Fast' buffers (see Fig.1). 'Damn Fast' was a humorous marketing slogan used for the LH0063,



National Semiconductor

Operational Amplifiers/Buffers

LH0033/LH0033C, LH0063/LH0063C Fast and Damn Fast Buffer Amplifiers

LH0033/LH0033C, LH0063/LH0063C

General Description

The LH0033/LH0033C and LH0063/LH0063C are high speed, FET input, voltage follower/buffers designed to provide high current drive at frequencies from DC to over 100 MHz. The LH0033/LH0033C will provide ±10 mA into 1 kΩ loads (±100 mA peak) at slew rates of 1500V/μs. The LH0063/LH0063C will provide ±250 mA into 50Ω loads (±500 mA peak) at slew rates of up to 6000V/μs. In addition, both exhibit excellent phase linearity up to 20 MHz.

- Output drive adequate for most loads
- Single pre-calibrated package

Features

- Damn fast (LH0063) 6000V/μs
- Wide range single or dual supply operation
- Wide power bandwidth DC to 100 MHz

Fig.1. Part of National Semiconductor's LH0033/LH0063 datasheet, proving that the LH0063 really was referred to as the 'Damn Fast Buffer" (From National Semiconductor's 1982 Linear Databook)

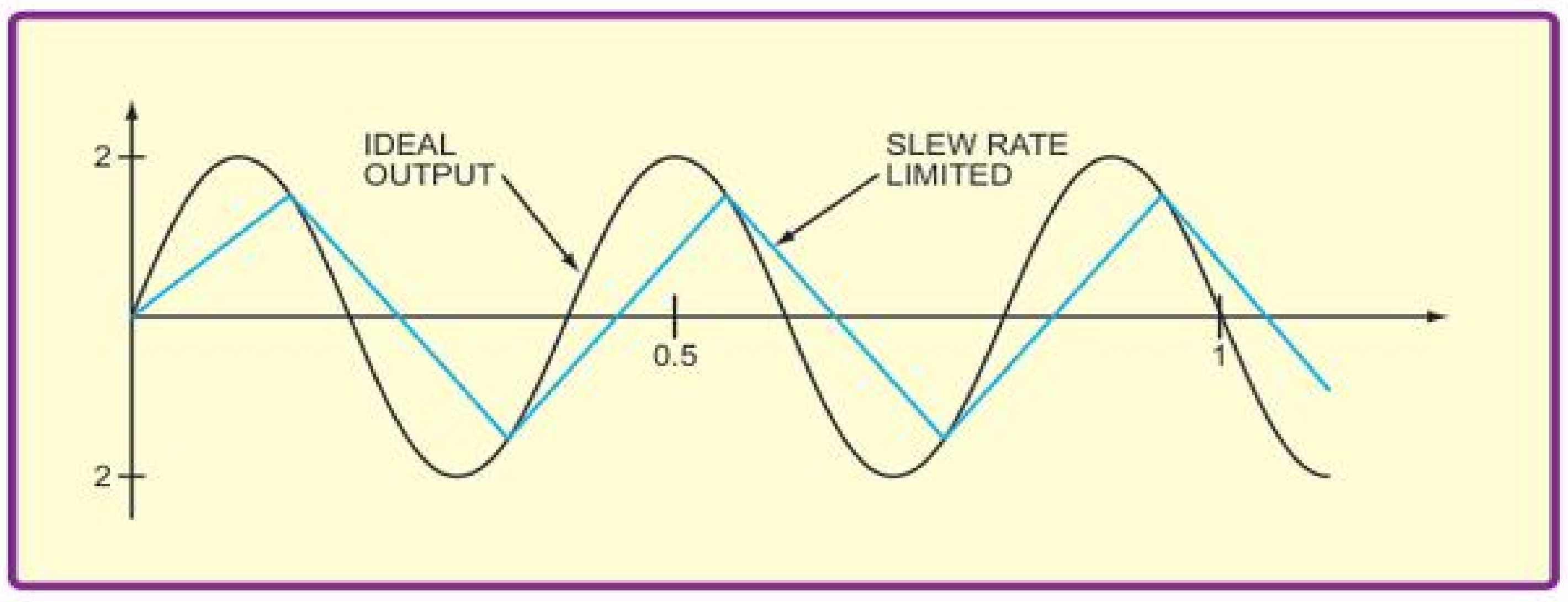


Fig.2. The output obtained from a circuit trying to produce a sinewave, but limited by slew rate to giving a triangular output

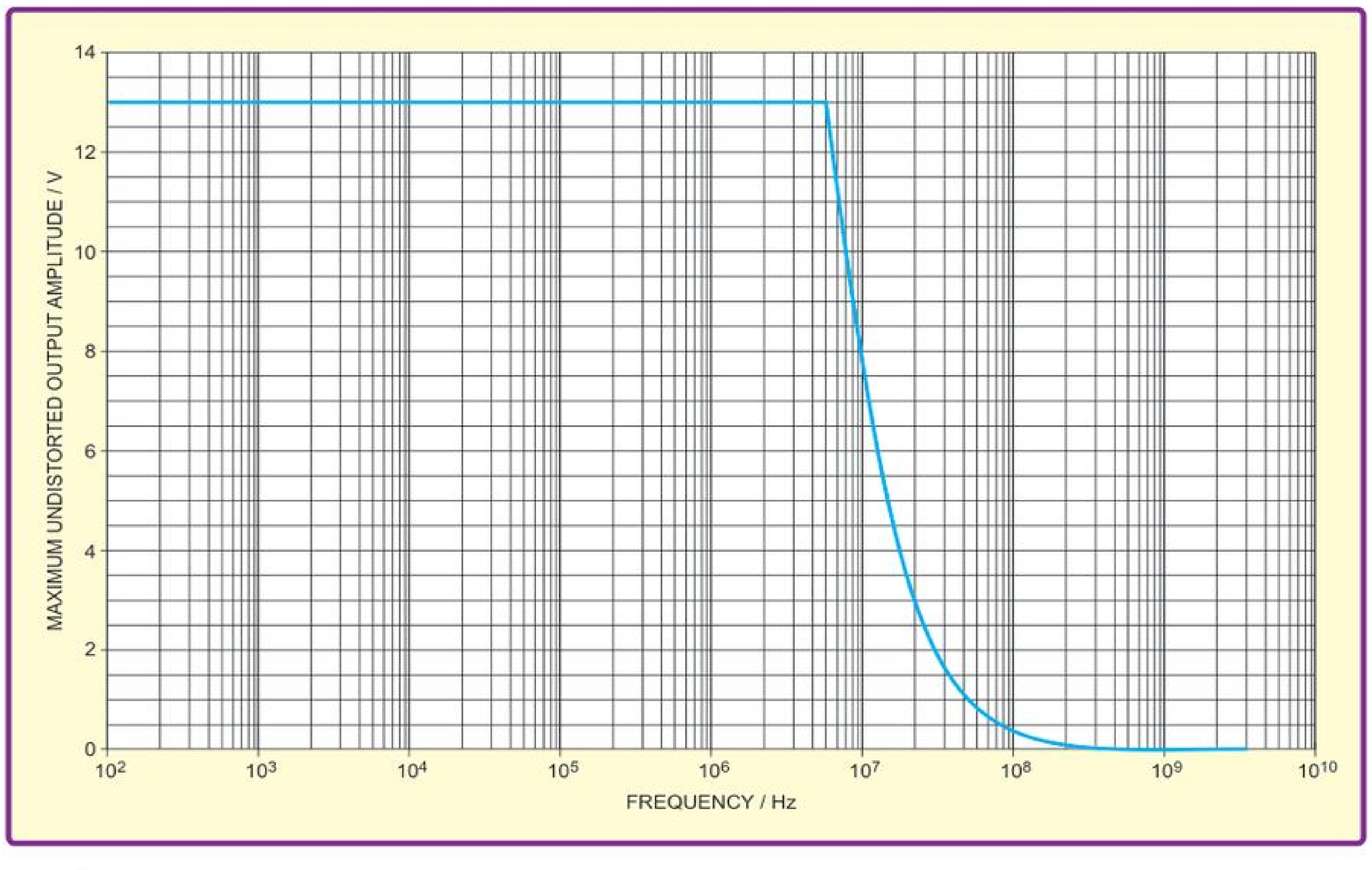


Fig.3. Maximum undistorted peak-to-peak output amplitude against frequency for a sinewave output from a 500V/μs slew rate buffer operating on a ±15V supply with an output signal range to within 2V of the supply. The full power bandwidth is about 6.1MHz

something which would probably never get past a semiconductor company's PR people in today's world. In fact, the description of the LH0063 has changed to 'Ultra Fast' on later datasheets. The LH0033 and LH0063 became obsolete in the late 1990s

Key parameters

Before looking at these and other buffer devices in more detail, it is a good idea to be clear about the key specifications which might be used to select the most appropriate device for an application. Parameters that may be of prime interest to designers using these devices include bandwidth, slew rate, settling time, supply and output voltage range, current output capability, quiescent current, and possibly differential gain and phase errors (for video).

The current and voltage capabilities are reasonably obvious, but note that a datasheet may specify both maximum continuous and peak current, and may also state short-circuit output current.

Quiescent current is important in low power systems (eg, battery operated), but in general, lowering quiescent (bias) currents may degrade other performance characteristics. Some devices allow the user to select between low power and higher performance modes.

Bandwidth, or more specifically, small signal bandwidth, is the frequency at which the gain of the buffer falls to 3dB below the gain at lower frequencies. The figure of 3dB is used because this is the point at which output power falls to half its value.

The small-signal bandwidth, as the name suggests, is defined with respect to a signal of arbitrarily small amplitude. The buffer will not be able to produce large amplitude signals right up to the small-signal bandwidth frequency.

Slew rate

Slew Rate, which was mentioned earlier in reference to National Semiconductors' fast buffers, is the maximum rate of change of the output voltage. Slew rates are often quoted in volts per microsecond (V/μs). For example, a value of 20V/μs would mean that the time that the circuit's output took to, say, change from 0 to 5V, due to a step change at the input would be 0.25μs (5/20000000).

Slew rates for high speed buffers are typically from, few hundred to a few thousand volts per microsecond. A fast device with a slew rate of 2500V/μs could change its output from 0V to 5V in 2ns.

The easiest way to think about slew rate is in terms of the response time to step change, as illustrated by the above examples. However, slew rate also determines the maximum peak-to-peak undistorted output for any type of waveform, including pure sinewaves.

At lower frequencies the maximum undistorted output from a circuit is usually determined by the power supply voltage, but as frequency increases the buffer's output cannot move fast enough to 'follow the shape' of large amplitude waveforms.

Fig.2 shows an extreme case, in which a slew-rate-limited output is failing to keep up with the required sinewave signal. The output chases the required signal shape as fast as it can (ie, at the slew rate) and this results in a triangular output instead of a sinewave. The rate of change of voltage on the triangle wave is equal to the slew rate. Less extreme cases will still result in distortion of the required signal.

If the required peak output voltage is V_m and the slew rate is S (in volts per second) the maximum frequency sinewave (in Hz) that can be output without distortion is known as the full-power bandwidth, or large-signal bandwidth, and is given by:

$$f = \frac{S}{2\pi V_m}$$

For example, for S=500V/μs and V_m=15V, the full power bandwidth is about 6MHz (as shown in Fig.3). For comparison, at 6000V/μs the full-power bandwidth at the same amplitude is about 64MHz. The full-power bandwidth can be surprisingly low for amplifiers with relatively low slew rates – just looking at the small-signal bandwidth is not sufficient if you need to output large amplitude signals.

At relatively low frequencies, the maximum output amplitude from a buffer is basically limited by the supply voltage. The output will be able to swing to within a certain voltage from the supplies – this will be another characteristic given on the datasheet. Beyond this amplitude, the waveform will clip, causing distortion.

At frequencies above the full power bandwidth slew-rate limiting will cause distortion at amplitudes below the maximum output swing. From this point upwards in frequency, the maximum undistorted output amplitude will decrease inversely proportional to frequency. This is illustrated in Fig.3.

Capacitive loads

Capacitive loads may prevent a buffer from achieving the datasheet slew rate due to the high currents required to charge and discharge capacitors at high speeds. The current, I_C, through a capacitor, C, is given by:

$$I_C = C\frac{dV_C}{dt}$$

where dV_C/dt is the rate of change of voltage across the capacitor. For example, to drive a 10nF capacitor at a slew rate of 1000V/μs requires a peak current of 10A, beyond the typical peak currents of buffer ICs.

Settling time

If the buffer is to be used to handle pulse signals or other situations where there are step change input voltages, specifications such as rise time and settling time may be of importance. Fig.3 shows the possible response of an amplifier to an instantaneous step or fast pulse input.

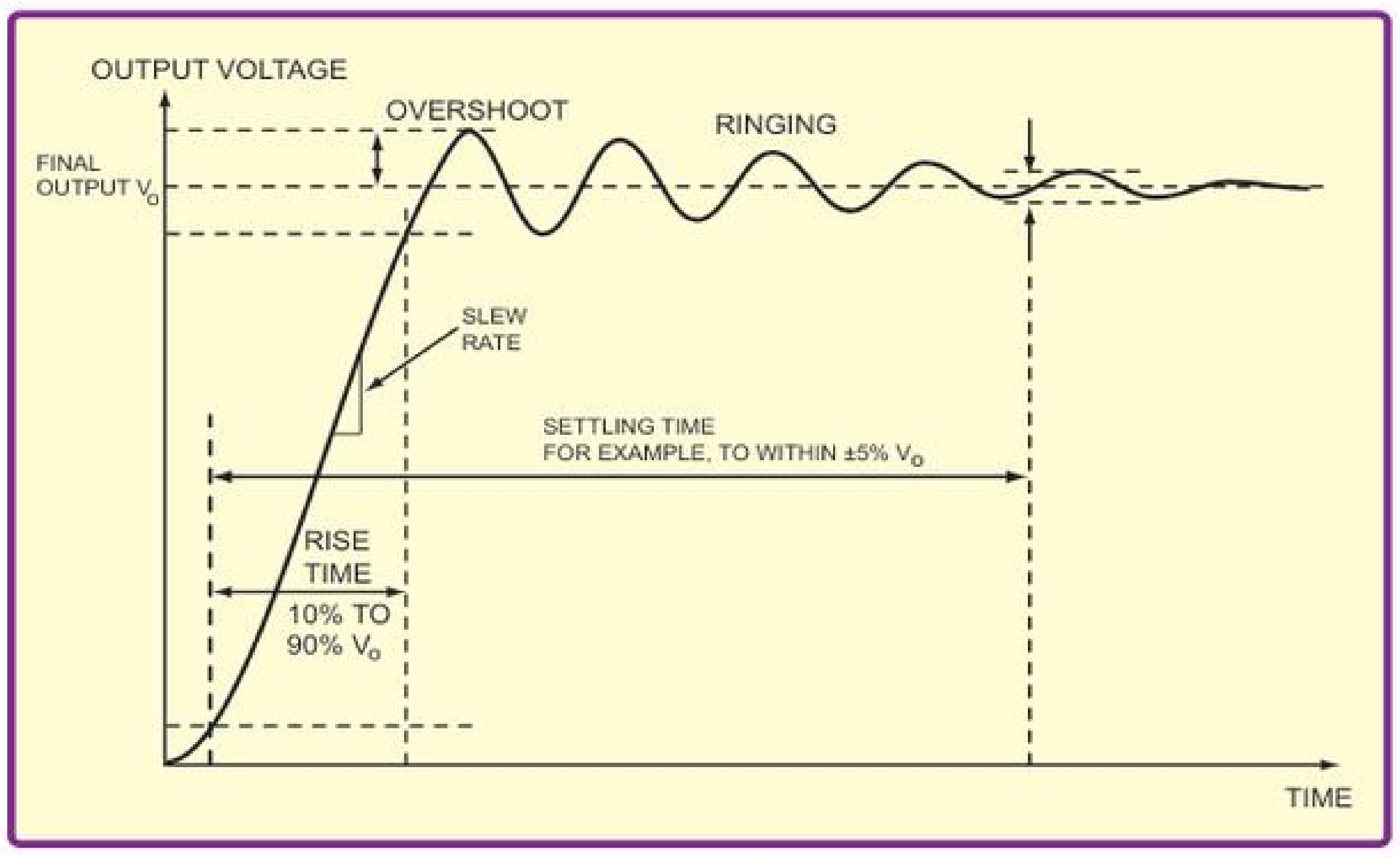


Fig.4. Time domain response of amplifier output

The output voltage will change at the slew rate towards the new output voltage, but may overshoot the required value, as shown in the Fig.4. This may in turn be followed by a decaying oscillation known as ringing. The output may, of course, also transition smoothly to the new value.

Either way, it will take a finite time to get within a certain percentage of the final value – this is the settling time. Settling time must be specified with respect to a given accuracy (percent of final value). The datasheet may specify more than one settling time (eg, to 1% and 0.1%).

Many high speed, high-current buffer ICs are targeted at video applications, and, therefore, the composite video-related specifications differential gain (error) and differential phase (error) are often quoted on datasheets. Seeing a differential gain specification for an amplifier with single-ended input and output may be confusing if you do not realise that these terms do not refer to differential input signals. Actually, like slew rate, these parameters indicate the linearity of the amplifier – its ability to accurately reproduce the shape of the input waveform.

A composite video signal has two parts – broadband and subcarrier. The broadband part controls the brightness (luminance) and the subcarrier part controls colour (chrominance). These two parts should not interact; that is, a change in brightness should not change the colour of an object in the video scene. The colour depends on the subcarrier amplitude (controlling saturation of colour) and phase (controlling the hue).

If a change in luminance level changes the amplifier gain, this will result in an unwanted change in colour intensity. If a change in luminance level changes the amplifier phase shift, then the colour will change hue. Differential gain (usually expressed as a percentage) is the error in the amplitude of the colour signal due to a change in luminance.

Similarly, differential phase (usually expressed in degrees) is the error in the phase of the colour signal due to a change in luminance. Good video buffers often have differential gain and phase errors of less than 0.1% and 0.1° respectively. This is much less than a human can perceive, but the errors accumulate if the signal passes through multiple amplifiers.

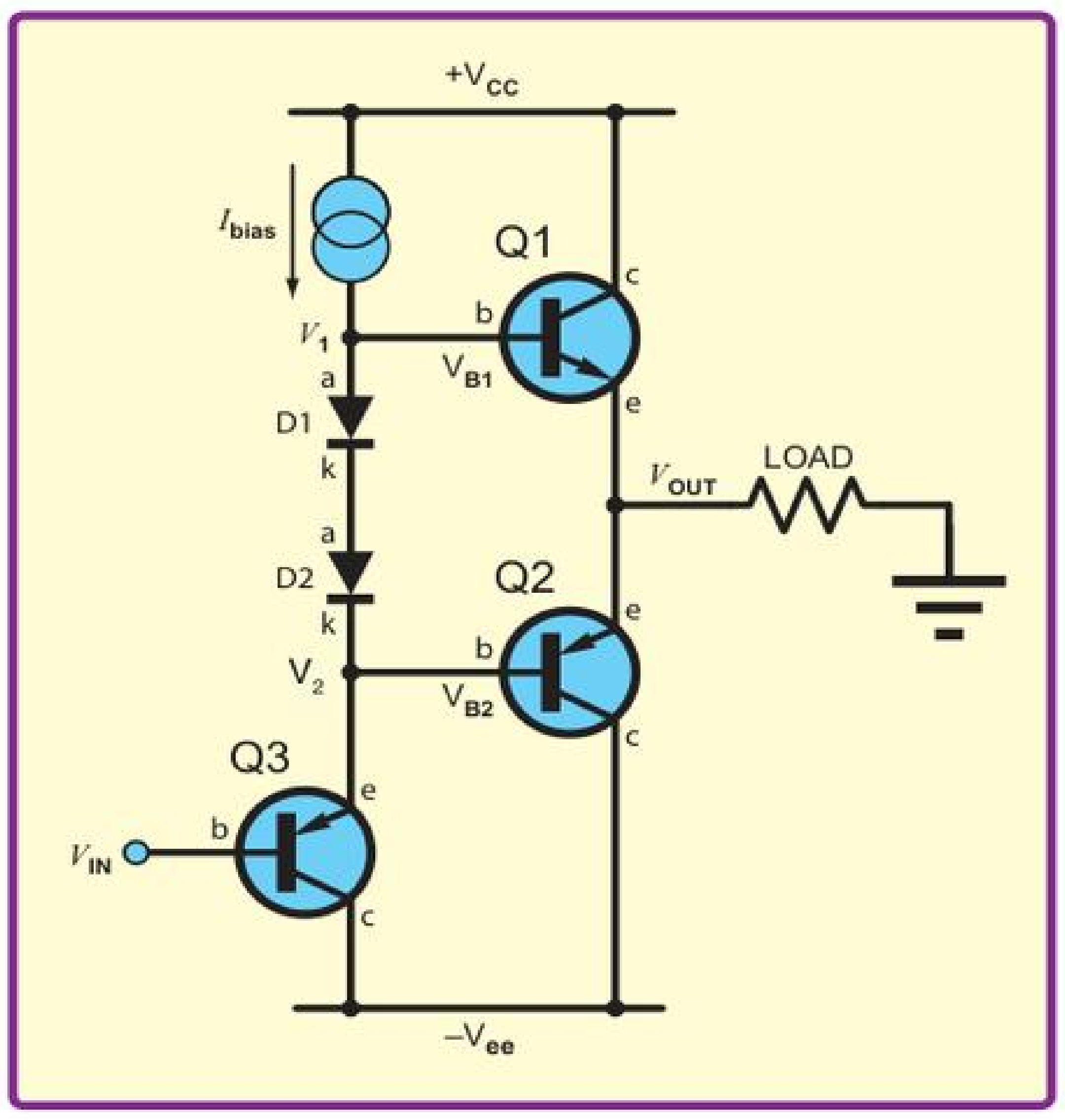


Fig.5. Using diodes to bias output transistors. The LH0033 used a similar approach, but with a JFET rather than bipolar input transistor

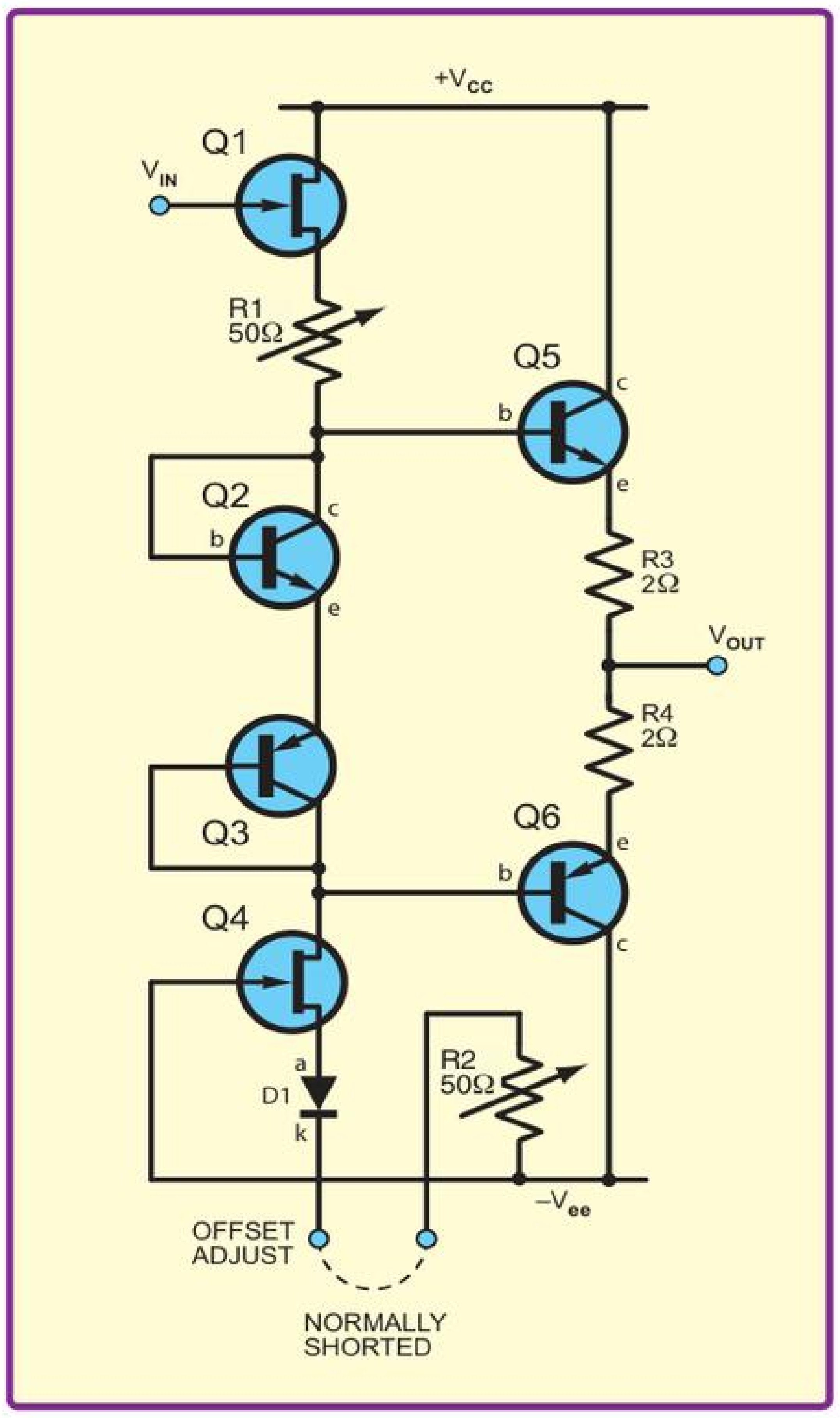


Fig.6. LH0033 schematic. Compare with Fig.5 – the diodes were implemented using transistors, with base shorted to emitter (National Semiconductor datasheet)

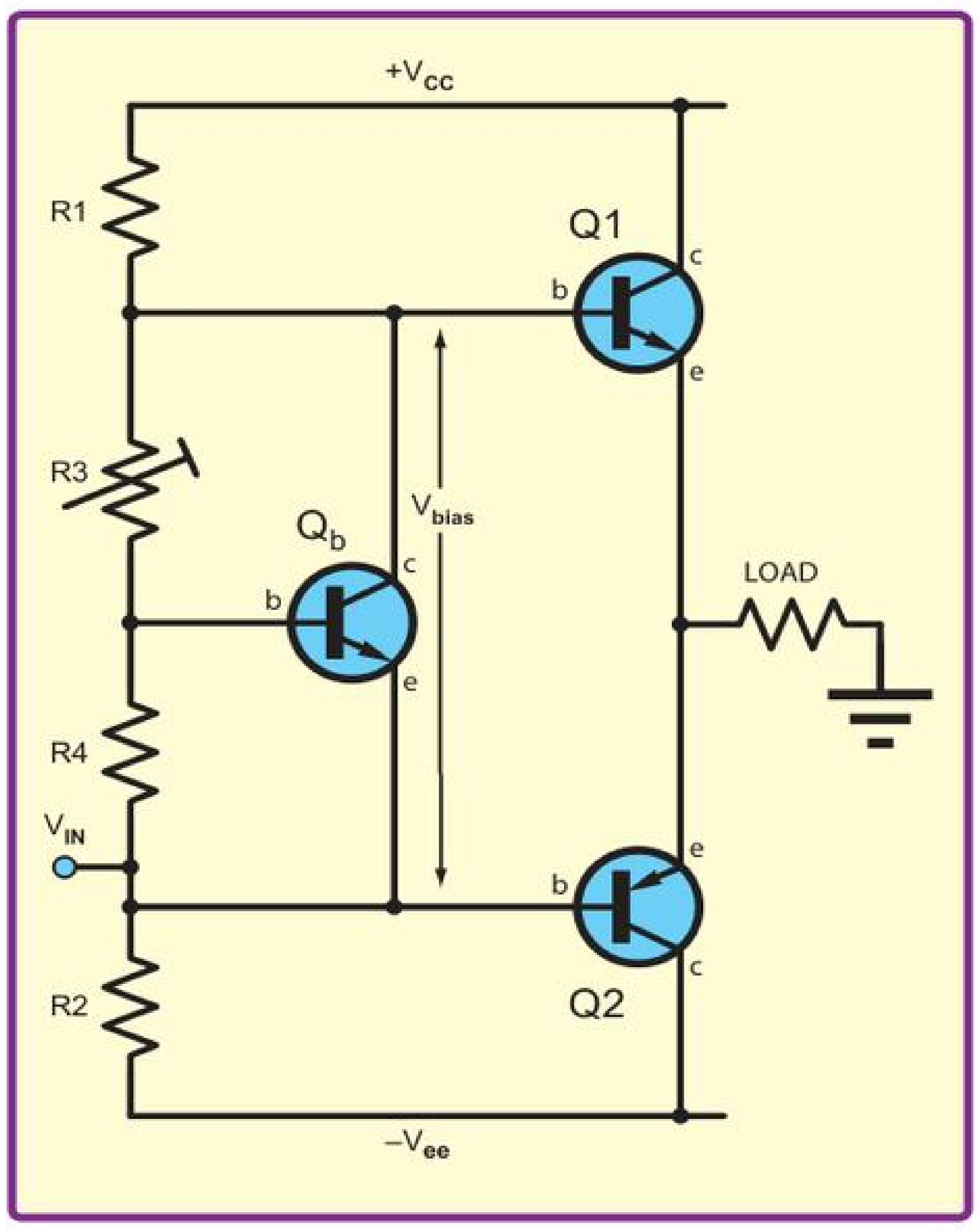


Fig.7. Output buffer using V_{BE} multiplier for biasing instead of diodes

Back to buffers

Returning to our discussion of specific devices, and recalling that last month we looked at a couple of basic buffer circuit structures, we can examine these circuits in use, at least where the datasheet gives us some idea of the device schematic. The LH0033 mentioned by atferrari used the diode-based biasing scheme we discussed last month. The circuit concept is shown again in Fig.5.

Fig.6 shows the schematic for the LH0033, which uses a very similar circuit. The diodes are implemented using transistors Q2 and Q3. The input signal is connected via JFET Q1. The bias current is supplied by JFET Q4. The current source and input transistor are swapped round compared with Fig.5, but the basic principle the same.

The LH0063 circuit uses a V_{BE} multiplier circuit, which we also discussed last month. The concept circuit is shown again in Fig.7. The LH0063 circuit is shown in Fig.8. The JFETs Q3 and Q4 provide bias current for the V_{BE} multiplier, rather than just resistors as in Fig.7. The input signal is coupled to the output transistors via a pair of complementary JFETS.

Another obsolete buffer is the LH0002. This used a different circuit configuration, as shown Fig.9. This circuit topology is widely used and is known as 'diamond buffer'. The input transistors Q1 and Q2 also produce the diode voltage drops required to bias the output transistors correctly.

Another couple of notable obsolete open-loop buffers are the Elantec EL2008 and EL2009. These featured 1A continuous output current and slew rates of 2500V/µs and 3000V/µs respectively. Elantaec is now part of Intersil. The EL2008/9 have been popular devices amongst DIY audio enthusiasts and have featured in many forum discussions.

BUF634 buffer

An in-production buffer based on similar principles to the LH0033/63, and particularly the LH0002, is the BUF634 from Texas Instruments. A simplified schematic of the device is shown in Fig.10, which reveals that, like the LH0002, it uses the diamond buffer topology. At the time of writing, individual devices cost around £7 plus VAT (from Farnell's website).

Looking at the BUF634 schematic, we can see that it includes output short circuit protection transistors, as we discussed last month. The strings of diodes from input to output also serve to protect the device. When operating correctly, the input and output voltages should be more or less the same (the device has unity gain). If the difference is greater than the voltage at which the strings of diodes conduct, the difference will be clamped at this level (about 3V), protecting the device.

However, under these conditions a large input current can flow (limited by the 200Ω resistor) which could damage the circuit driving the BUF634. The chip also features thermal shutdown to protect from overheating.

The bias currents in the BUF634 are set by the circuit shown in the bottom left of the schematic (Fig.10). An

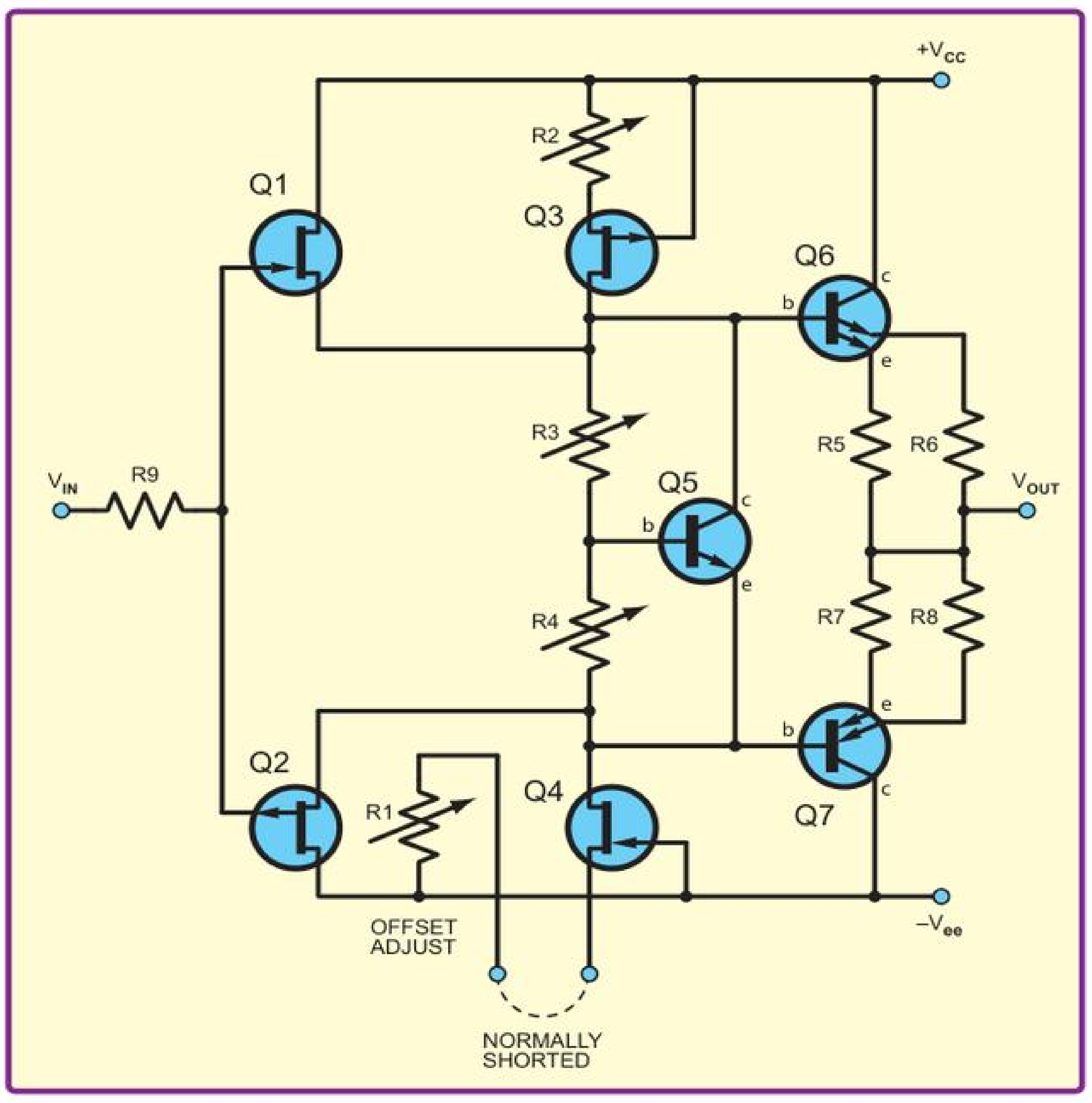


Fig.8. LH0063 circuit, which uses the bias scheme shown in Fig.7 (National Semiconductor datasheet)

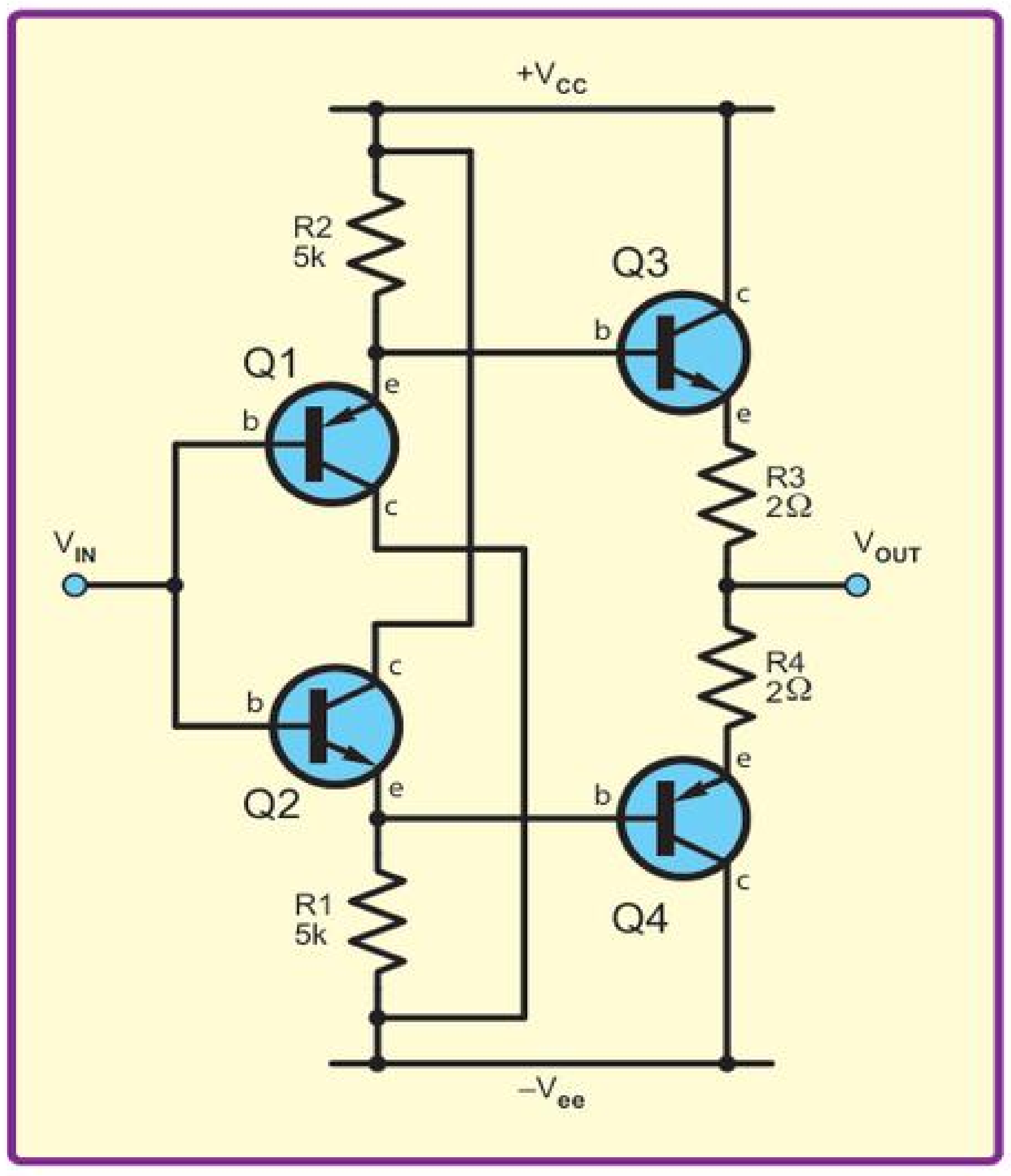


Fig.9. (left) Diamond buffer topology used in the LH0002 (National Semiconductor datasheet)

external connection (BW pin) allows the user to modify the bias current. The small-signal bandwidth of the BUF634 is approximately 30MHz in low quiescent-current mode (1.5mA), which occurs when the BW pin is unconnected. Bandwidth can be extended to approximately 180MHz by connecting the BW pin to the negative supply. This quiescent current is then about 15mA. Intermediate bandwidths can also be set using suitable resistors.

Feedback loop

The BUF634, and other similar open-loop buffers, are often used within a feedback loop with an op amp, as shown in Fig.11. Correct choice of op amp is important and guidance is given in the datasheet. The feedback reduces offsets and output impedance and allows higher output currents to be achieved. If a single device cannot provide enough current they may be connected in parallel.

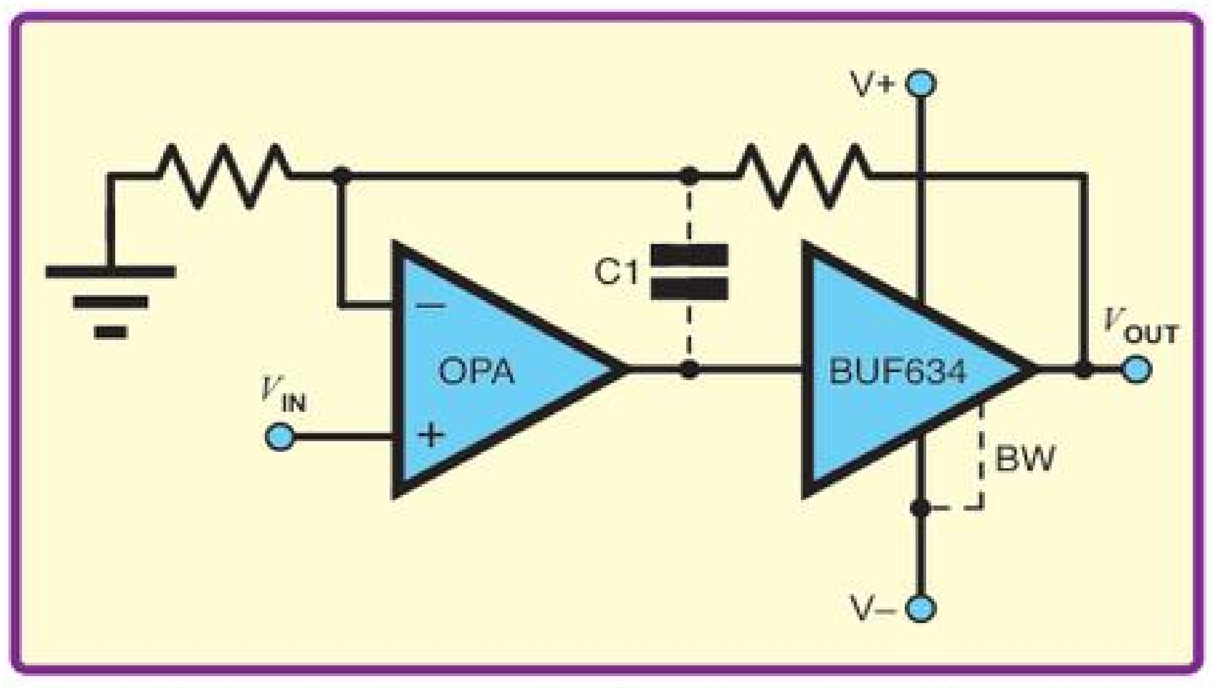


Fig.11. Including a buffer in a feedback loop with an op amp (National Semiconductor/ Texas Instruments BUF634 datasheet)

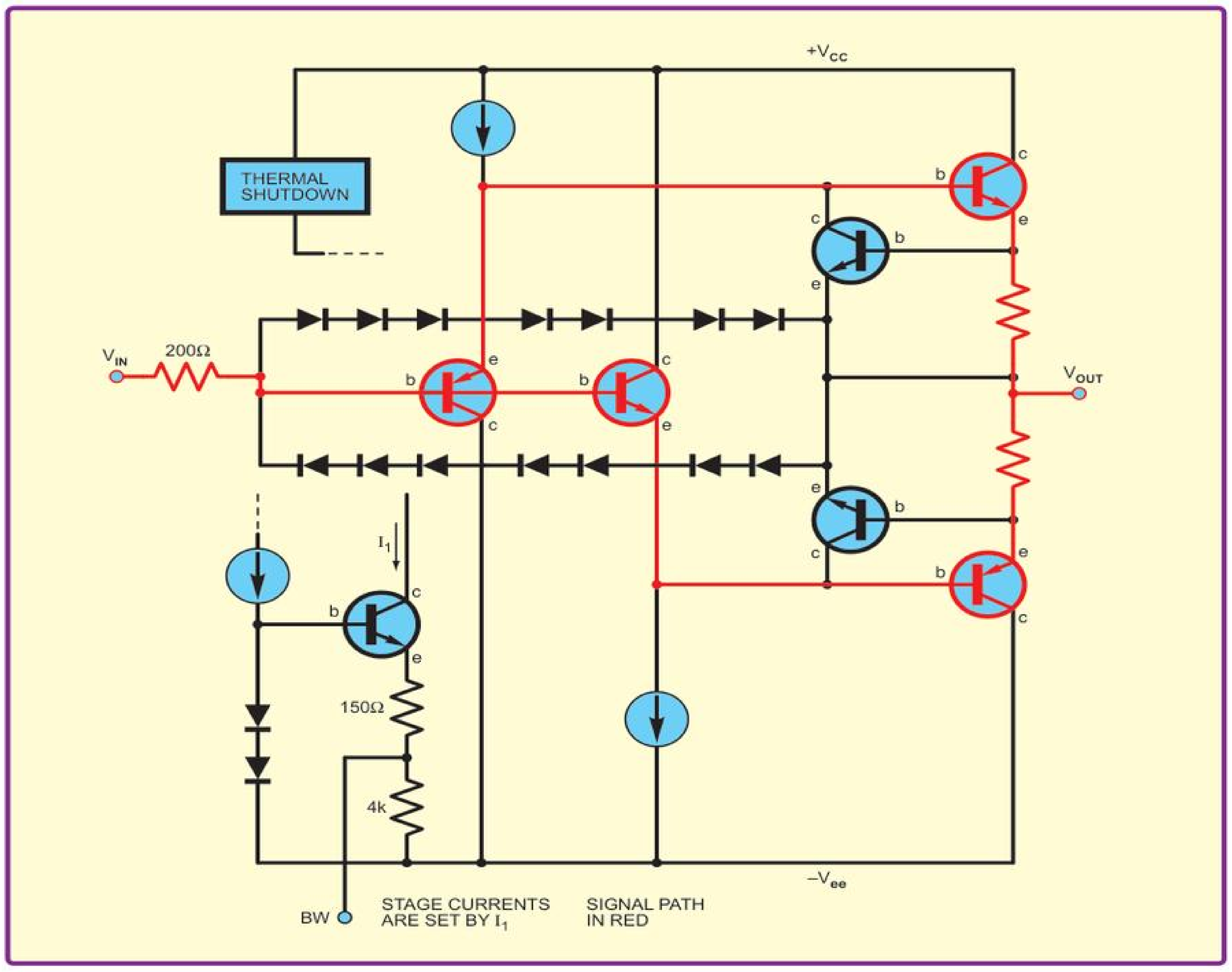


Fig.10. BUF634 schematic. Like the old LH0002, this uses a diamond buffer topology (National Semiconductor/Texas Instruments datasheet)

Circuit design

As will all high speed circuits, care must be taken with circuit design and layout when using these chips. Supply decoupling must be used. If the devices are used with high output currents, good thermal design (heatsinking) will be required. The datasheet also provides guidance on this.

Atferrari asked if an IC-based design would be better than one built from discrete components. There is not a definite answer to this.

An IC-based design will be simpler and more compact (fewer components) and probably easier to get working. A discrete design may achieve higher performance – if your circuit design and construction skills are sufficiently good. It will probably also be more tweakable.

A discrete design will probably take more time, at least if designing from basic principles, rather than using a published circuit, but it may well teach you more about circuits in the process (if that is your objective).

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INTERFACE

Analogue output port update

RECENT *Interface* articles have covered a simple 8-bit analogue input port based on an FT245RL chip or its UM245R development module. A simple 8-bit latching output port based on the same chip/module was covered prior to this, and in this month's article we will return to this circuit (Fig.1).

To be more precise, we will return to the Visual BASIC Express 2010 software associated with this circuit. As pointed out in the earlier article, there was a problem when using the output port with strings, in that the most significant output line was always zero, even if character values above 127 were used.

A bit short

This would not be a problem when using normal 7-bit ASCII characters, but it would clearly not give the desired result with any form of extended 8-bit character set. It also meant that the ploy of outputting bytes of data via a string value conversion only gave 7-bit operation, leaving the most significant output line (D7) unusable.

Due to difficulty in getting the software to simply write bytes of data to the interface, this was the method adopted for the software I originally used with the interface. Some delving on the Internet suggests the cause of the problem is 7-bit coding being used by default, but 8-bit coding can be obtained by using a program line such as:

```
System.Text.Encoding.GetEncoding(“Windows-1252”)
```

In the current context at any rate, I did not find that this helped, and 7-bit operation was still obtained. However, further delving revealed that there is an easier way of handling things when it is necessary to output bytes of numeric data to the port. The obvious way is to use the WriteByte method. Unfortunately, I have not managed to get this method to work on my computer system, although the ReadByte way of reading bytes of data worked flawlessly and has been featured in previous *Interface* articles.

A method used with some commercial devices that interface to a PC via a virtual serial port is to send an array to the port. In some cases, it is strings of characters that are sent, while in others it is bytes of numeric data. For example, a button could have this code included in its subroutine:

```
Dim databs(4) As Byte
databs(0) = 255
databs(1) = 128
databs(2) = 1
databs(3) = 0
SerialPort1.Write(databs, 0, 4)
```

First, an array of four bytes called ‘databs’ is created, and then values are assigned to each element of the array. Finally, the four values are written to the port in the correct sequence. This method is very useful for an ‘intelligent’ device based on a microcontroller where the first byte could be a code telling the device the type of operation it must perform, and the next three bytes could be control data, values to be output on ports, or whatever.

All for one

On the face of it, this method is less useful for a simple interface that requires individual bytes of date rather than sequences, but it can actually be used in this role. A single element array is an oxymoron if ever there was one, but Visual BASIC 2010 Express is quite happy to create a byte array having just one element, and its contents can then be sent to a serial port using the normal Write instruction.

In the demonstration program of Listing 1, the form must have a horizontal scrollbar set to give values from 0 to 255. The program includes five lines that set the appropriate parameters, but these can be set via the scrollbar's properties Window if preferred. The starting value is set at zero, but if necessary a different value can be used here. This control is, of course, used to provide the bytes

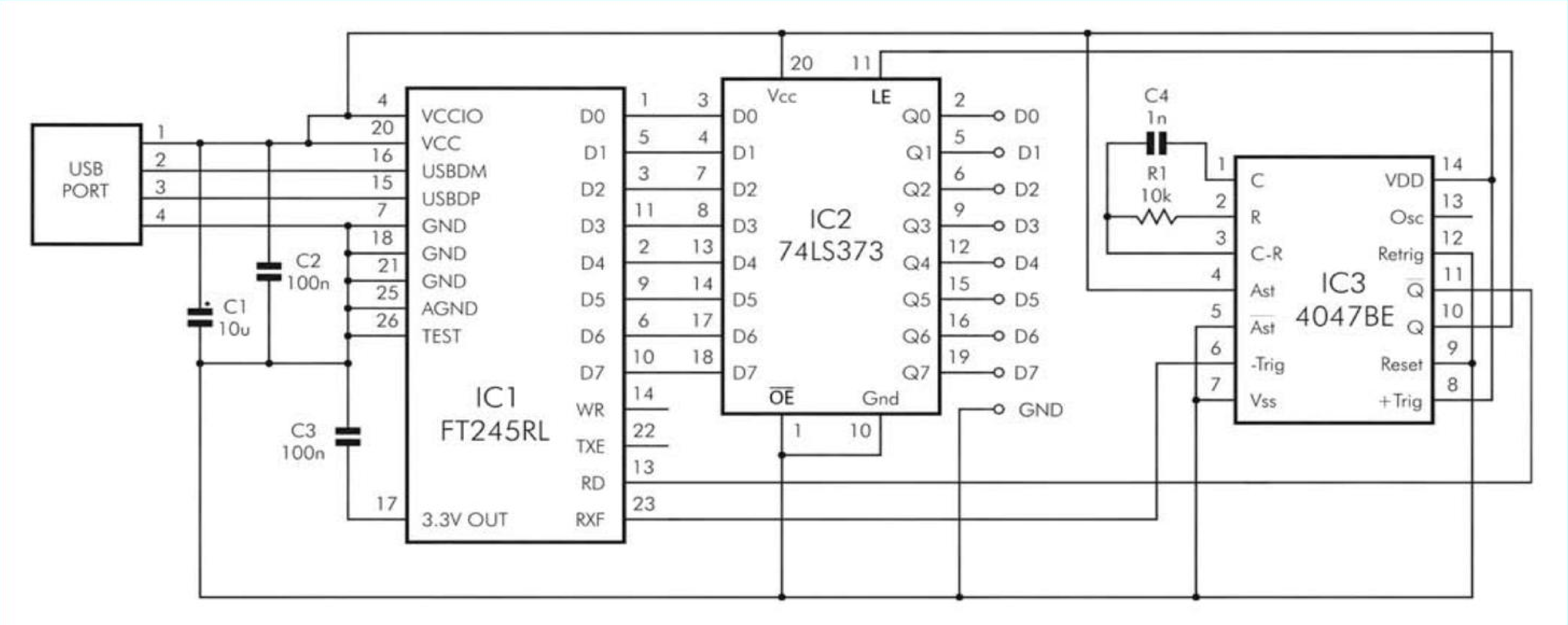


Fig.1. The circuit diagram for the simple 8-bit output port. With the new version of the controlling software it provides full 8-bit operation and is no longer restricted to 7-bit use

of data that are sent to the port. When using other sources, it is essential to ensure that they will only provide valid byte values (integers from 0 to 255).

The program also requires a label component, and this is used to display the last value sent to the port. Of course, the SerialPort component must also be included, and for use with the simple latching 8-bit output it must be set for an 8-bit word format and for 9600 baud operation. It must also be set to use the correct serial port (COM) number for the port you are using. The port assignments can be found in the Ports section of the Windows Device Manager utility.

The code for the horizontal scrollbar's subroutine first creates the single-byte array, and then the new value from the scrollbar is written to the Label component. Next, the single byte in the array is set at the new value from the scrollbar, and then this value is written to the serial port. In practice, this method was found to work flawlessly, giving full 8-bit operation and the appropriate binary patterns on the outputs of the port. Fig.2 shows the demonstration program in operation, with no error messages in evidence!

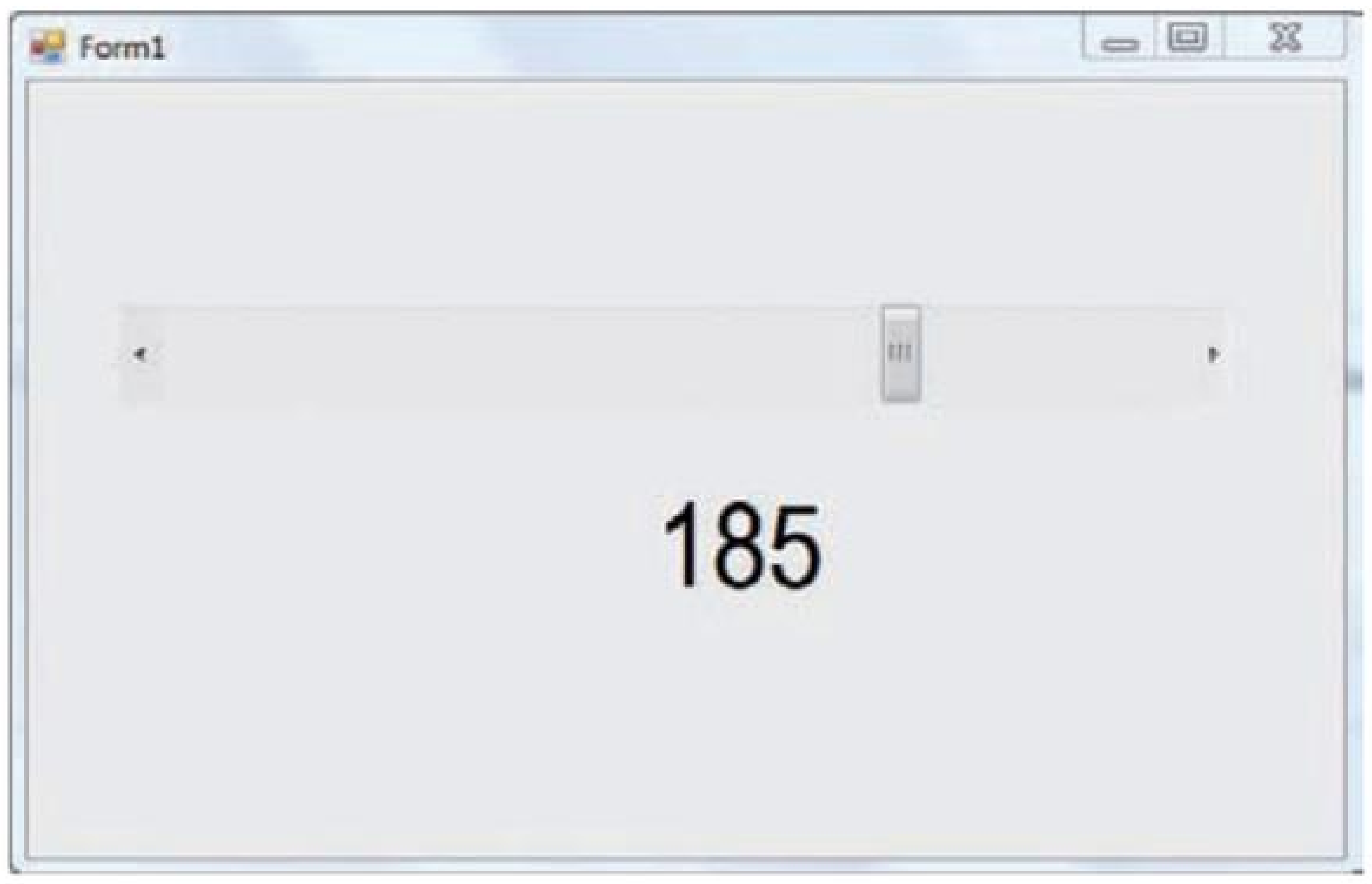
Listing 1

```
Public Class Form1

  Private Sub Form1_Load(sender As System.Object, e As
    System.EventArgs) Handles MyBase.Load SerialPort1.Open()

    HScrollBar1.SmallChange = 1
    HScrollBar1.LargeChange = 1
    HScrollBar1.Minimum = 0
    HScrollBar1.Maximum = 255
    HScrollBar1.Value = 0

  End Sub

  Private Sub HScrollBar1_Scroll(sender As System.Object, e As
System.Windows.Forms.ScrollEventArgs) Handles HScrollBar1.Scroll

    Dim databs(1) As Byte
    Label1.Text = HScrollBar1.Value
    databs(0) = HScrollBar1.Value
    SerialPort1.Write(databs, 0, 1)

  End Sub
End Class
```

Pulsed controller

A pulsed controller circuit for use with 12V DC motors accompanied the virtual serial port interface in the original article, but this only gave 7-bit operation due to the problems in outputting 8-bit values to the interface. With the new software, it is possible to take advantage of the additional output line. One way of doing this would be to use it to control a relay via a simple driver circuit. A set of double-pole changeover relay contacts could then be used to control the polarity of the output voltage, which would provide direction control.

Alternatively, the full 8-bit resolution of the digital-to-analogue converter (DAC) can be realised, and this approach will be considered first. Full 8-bit operation is provided by the modified controller circuit of Fig.3. The least-significant bit was connected to ground in the original circuit, and the other inputs were driven from the seven least-significant outputs of the interface. This gave virtually the normal full-scale output voltage from the converter (2.54 rather than 2.55V), but with only half the normal resolution.



185

Fig.2. The simple controller program in operation. Values of 128 or more now bring output D7 into action

With the revised circuit, the eight outputs of the interface simply connect to their equivalent inputs of the converter. This gives the full 2.55V maximum output potential and the converter chip's full resolution of 10mV. The converter circuit is powered from the 5V supply of the USB port, and the rest of the circuit can be omitted if you simply need a basic analogue output port.

The pulsed controller requires a reasonably well regulated and smoothed 15V supply that should

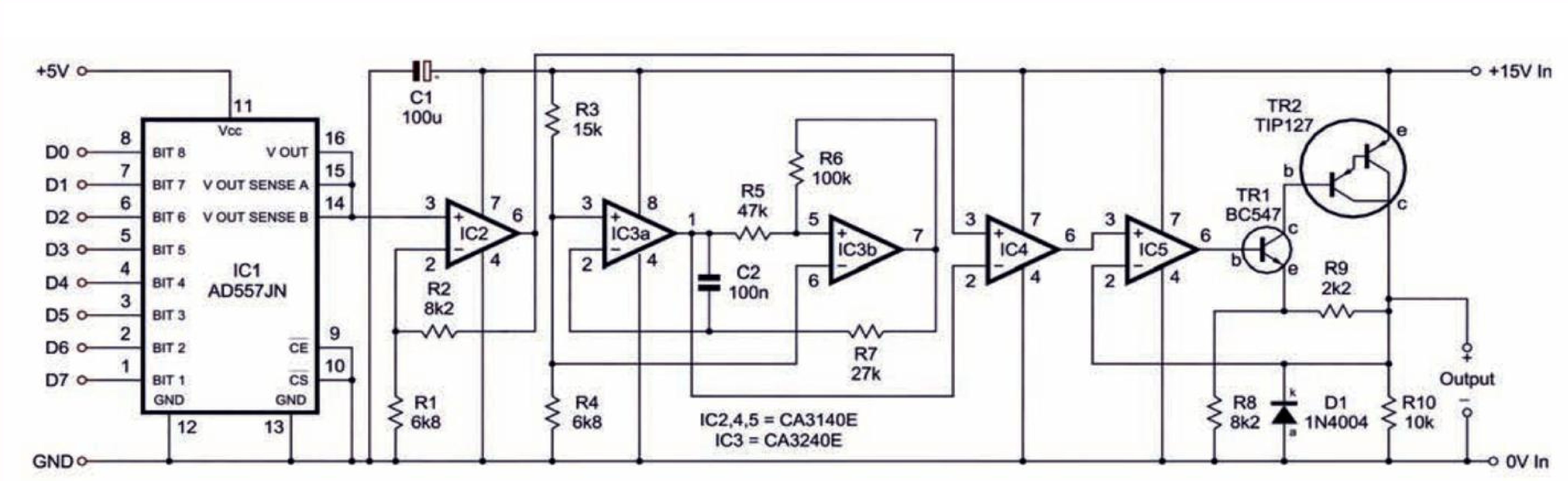


Fig.3. This modified version of the pulsed controller, in conjunction with the new version of the software, gives full 8-bit operation. The average output voltage increments in steps of just less than 50mV (0.05V)

Listing 2

```
    Sub HScrollBar1_Scroll(sender As System.Object, e As
System.Windows.Forms.ScrollEventArgs) Handles HScrollBar1.Scroll

        Dim databs(1) As Byte
            databs(0) = HScrollBar1.Value
        If databs(0) < 128 Then databs(0) = (127 - databs(0))
        Label1.Text = databs(0)
        SerialPort1.Write(databs, 0, 1)

    End Sub
```

be capable of providing a maximum current that is slightly higher than the highest load current that will be drawn from the controller. There is no form of over-current protection built into the controller circuit, so the power supply circuit must provide current limiting at a suitable level. The controller can handle output currents of up to about 2A.

Due to the switching nature of the output stage, the dissipation in output transistor TR2 is relatively low. However, at high output currents it still has to dissipate a few watts. It should, therefore, be fitted with a heatsink to a rating of about 10°C per watt or better. All four integrated circuits are MOS types and require the usual anti-static handling precautions.

As explained previously, an output voltage range of 0V to 2.55V with 10mV resolution is obtained from the AD557JN converter chip. The signal processing stages provide a voltage gain of nearly five, which gives a resolution at the output of a little under 50mV. In a motor control context, and in most other applications, this should be sufficient to avoid any obvious stepping as the output is taken from one level to the next.

Relay control

Seven-bit operation, including direction control, can be obtained using the original controller circuit plus a relay driver circuit, such as the one shown in Fig.4. This is just a simple common-emitter switching transistor (TR1) that activates the relay when a logic 1 output level is produced on output D7 of the interface. A set of double-pole changeover contacts is used to control the polarity of the controller's output signal.

The relay contacts should have a current rating of at least 2A. Although the relay is used on a 15V supply, any 12V type should be able to operate at this supply level, and a 12V component will probably be easier to obtain.

The control characteristic of the controller is a little odd when direction control is added. Values from 0 to 127 give a range of output levels from zero to maximum in the normal way. However, the speed drops back to zero when the value sent to the interface reaches 128, At this point, output D7 goes high and the polarity of the output signal is reversed. Values from 128 to 255 then provide a range of output levels from zero to maximum, but with the polarity of the output signal still reversed of course.

The modified scrollbar subroutine of Listing 2 gives a more useable control characteristic. Some simple mathematics is applied to the value from the scrollbar before it is output and displayed. Raw values from 128 to 255 give a range of speeds with reversed polarity, as before.

However, values from 0 to 127 are inverted before being output and displayed. In other words, values from 0 to 127 from the scrollbar are output as values from 127 to 0. The output level therefore increases as the slider is moved downwards and away from the central 'off' position. This avoids having a sudden jump from maximum to zero power as the scrollbar's value goes from 127 to 128, and makes the controller much easier to use.

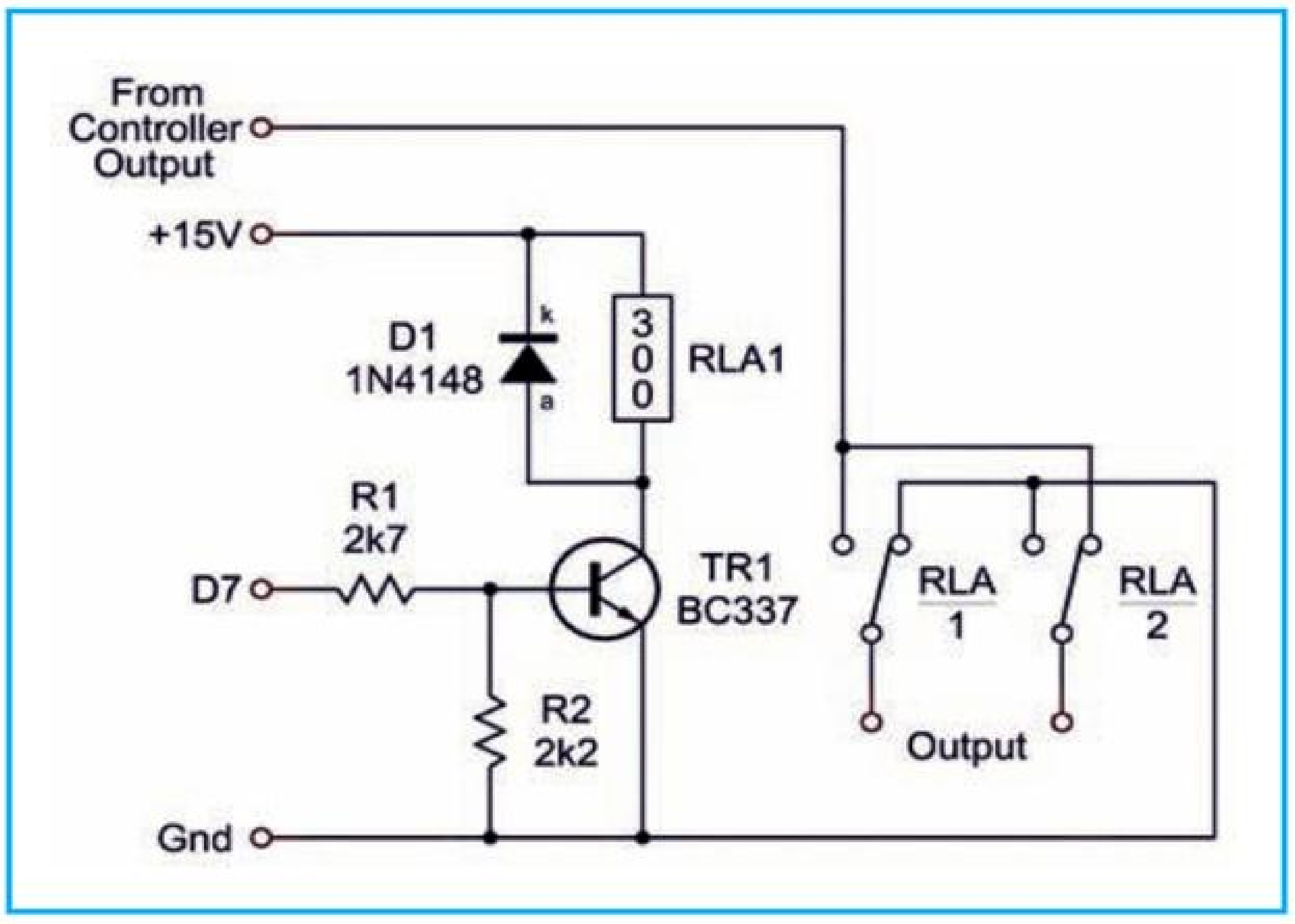


Fig.4. A simple relay driver circuit that provides direction control. It is controlled by output D7 of the interface, which must, therefore, be used with the 7-bit version of the controller.

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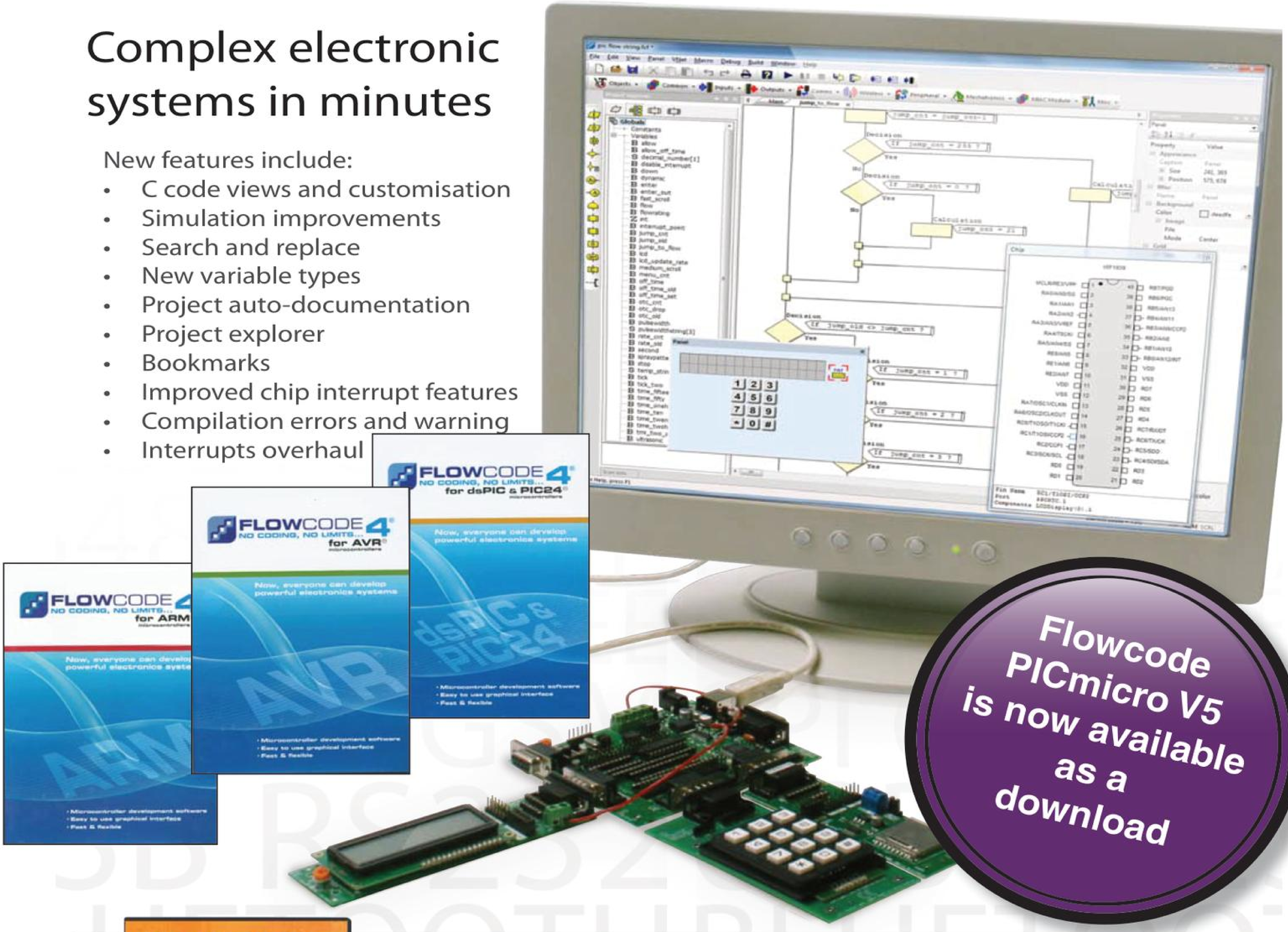
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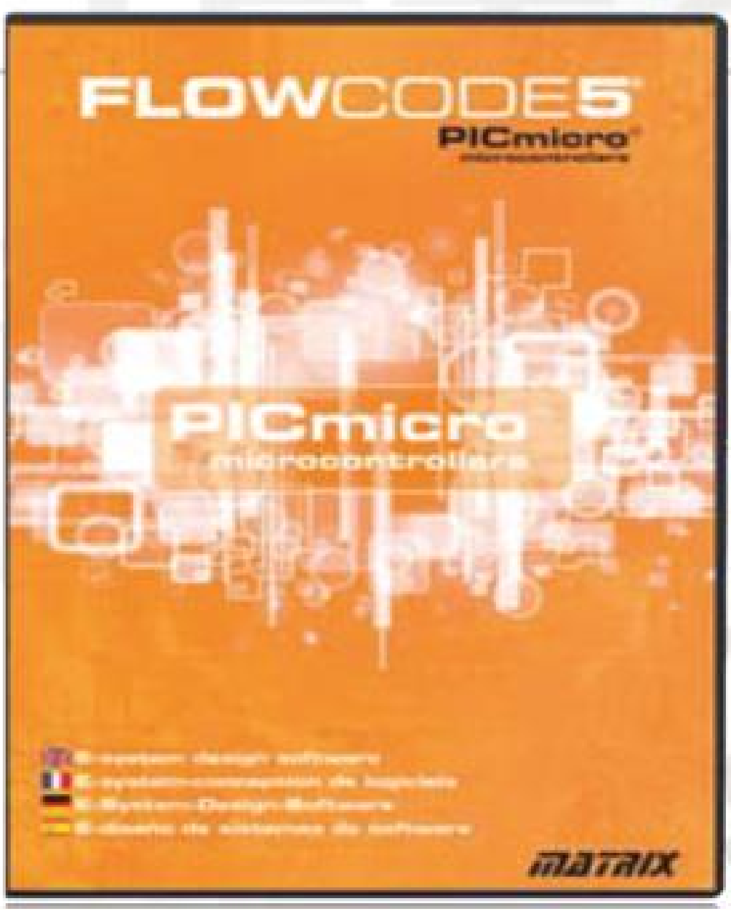
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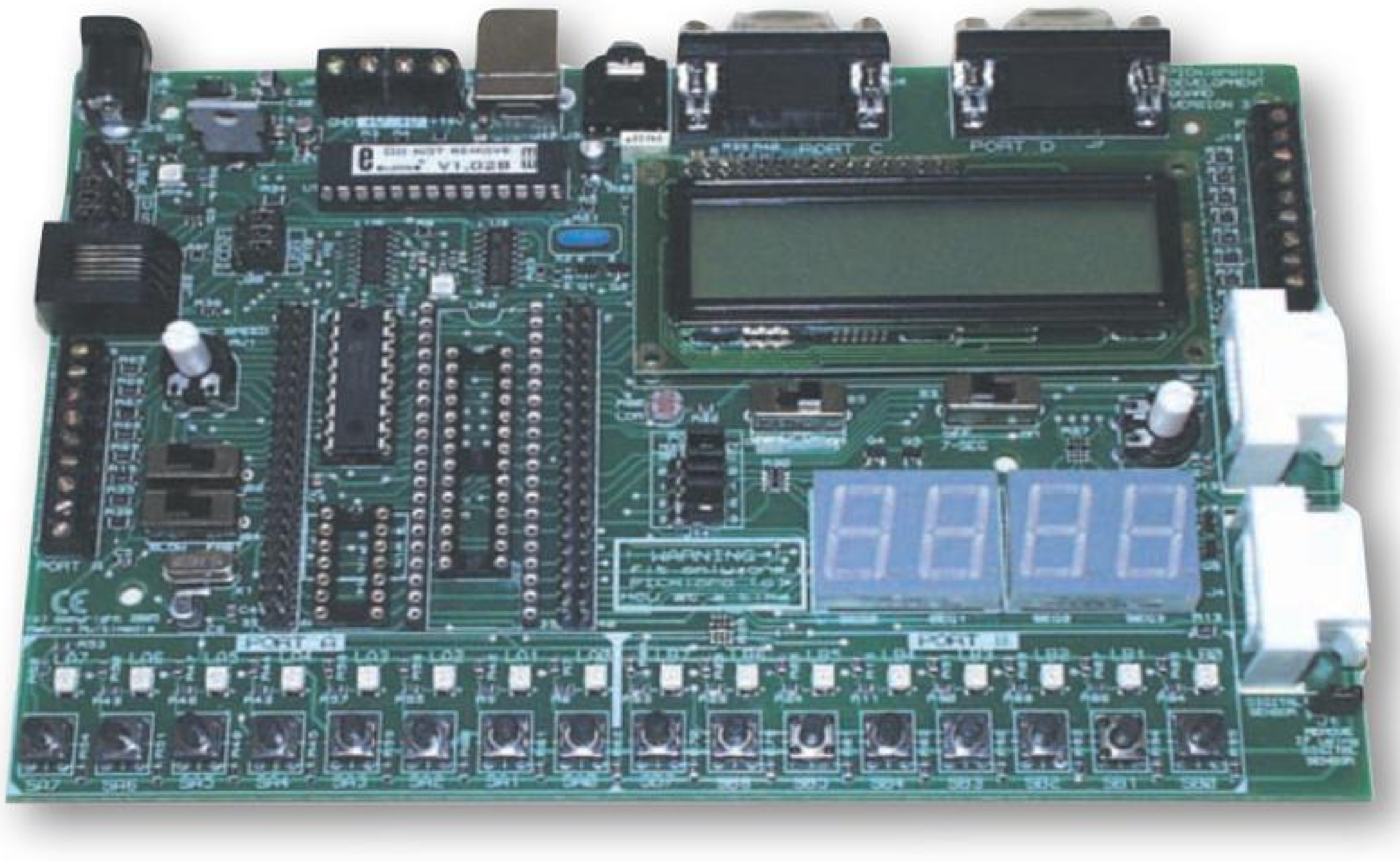

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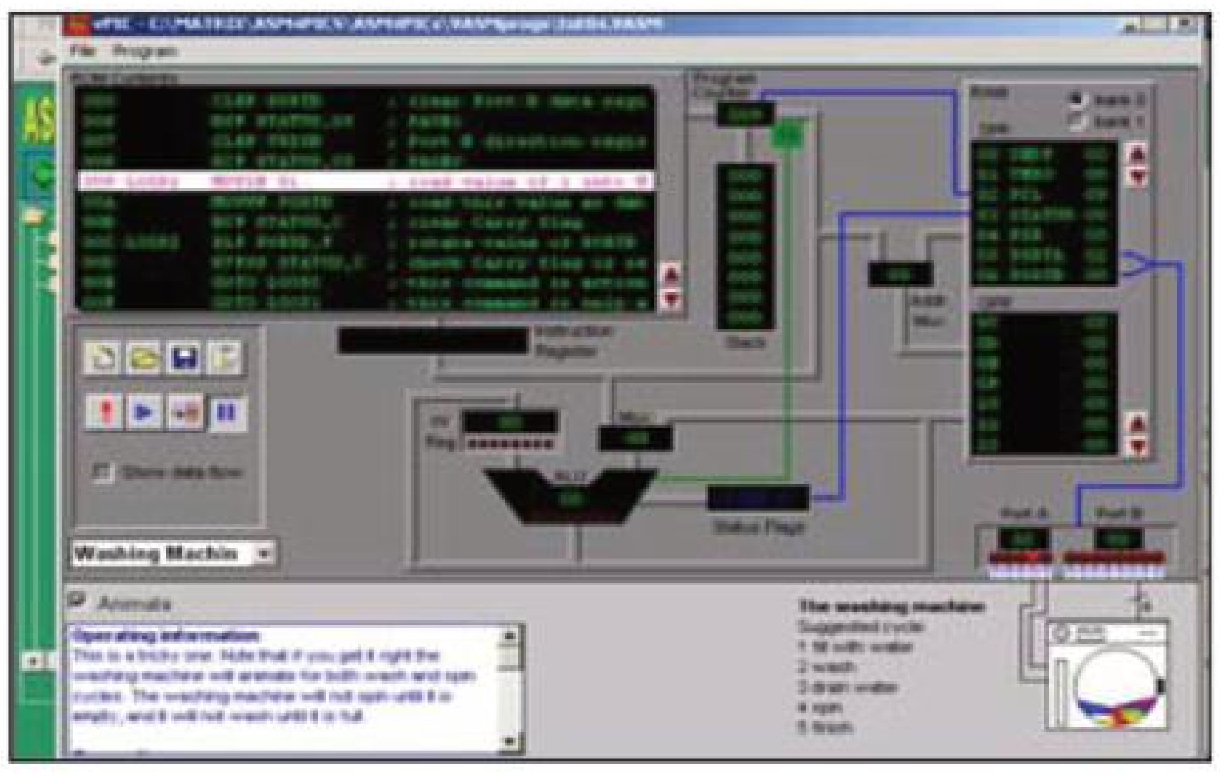

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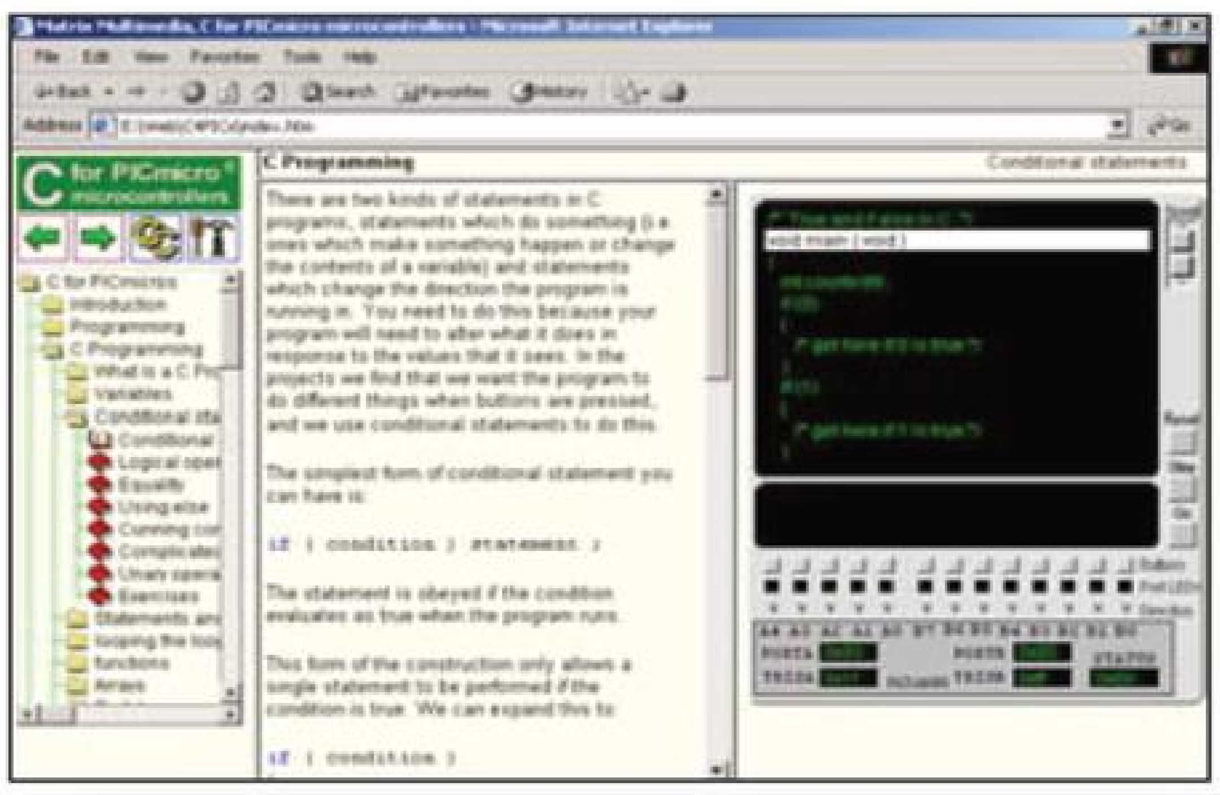

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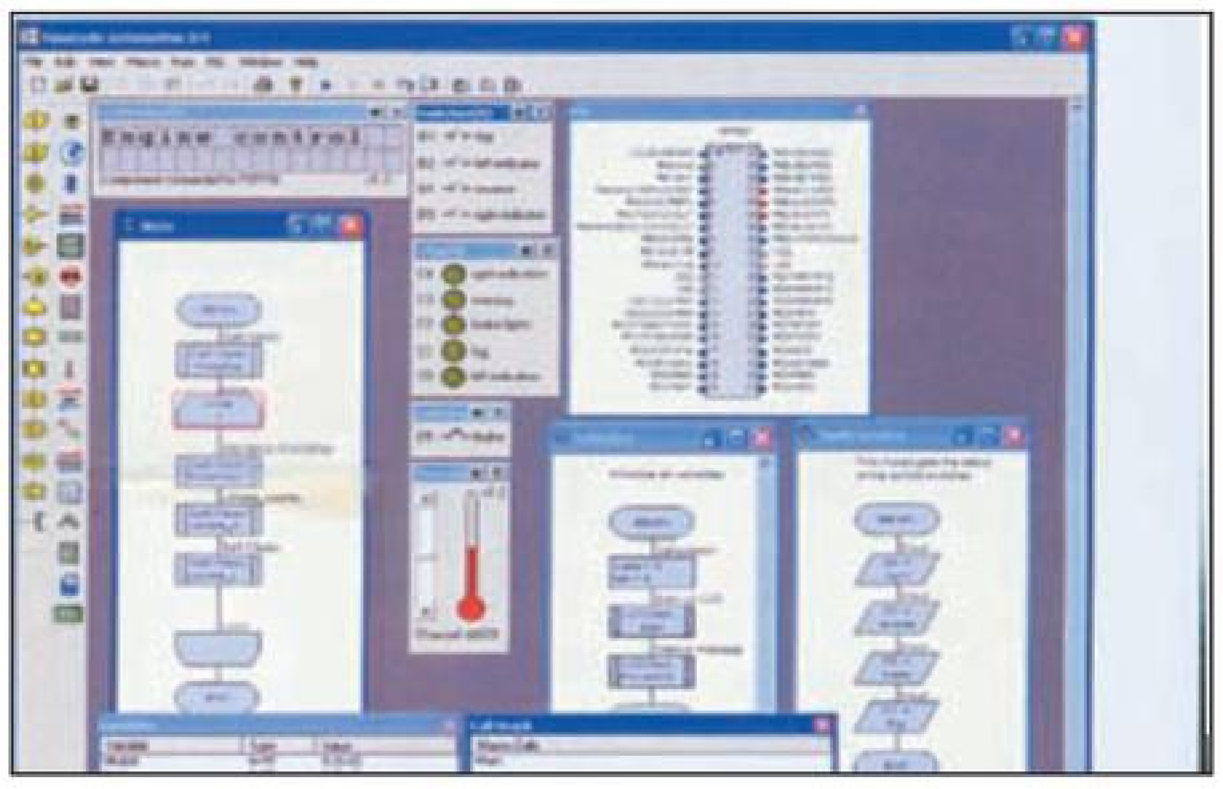

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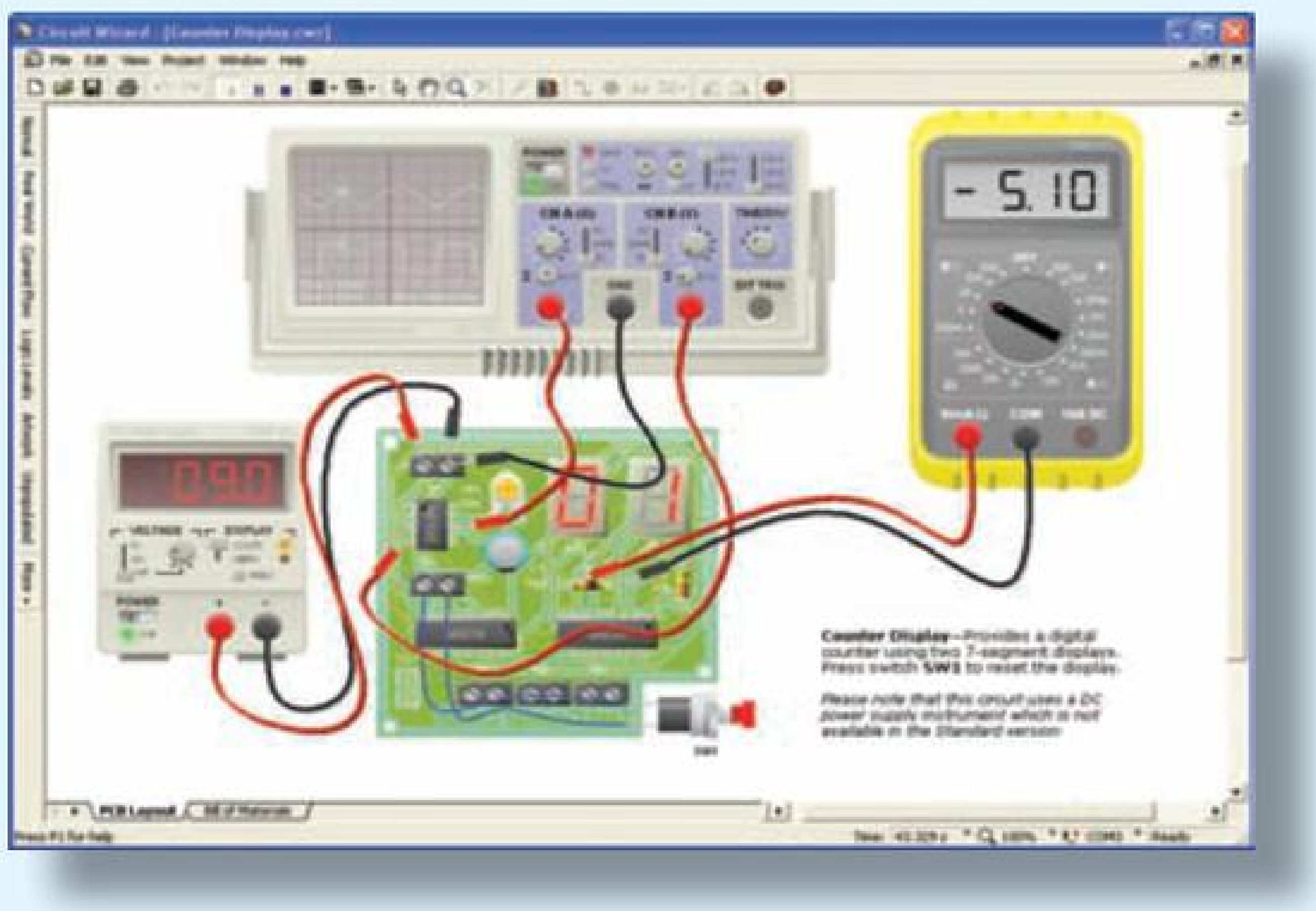

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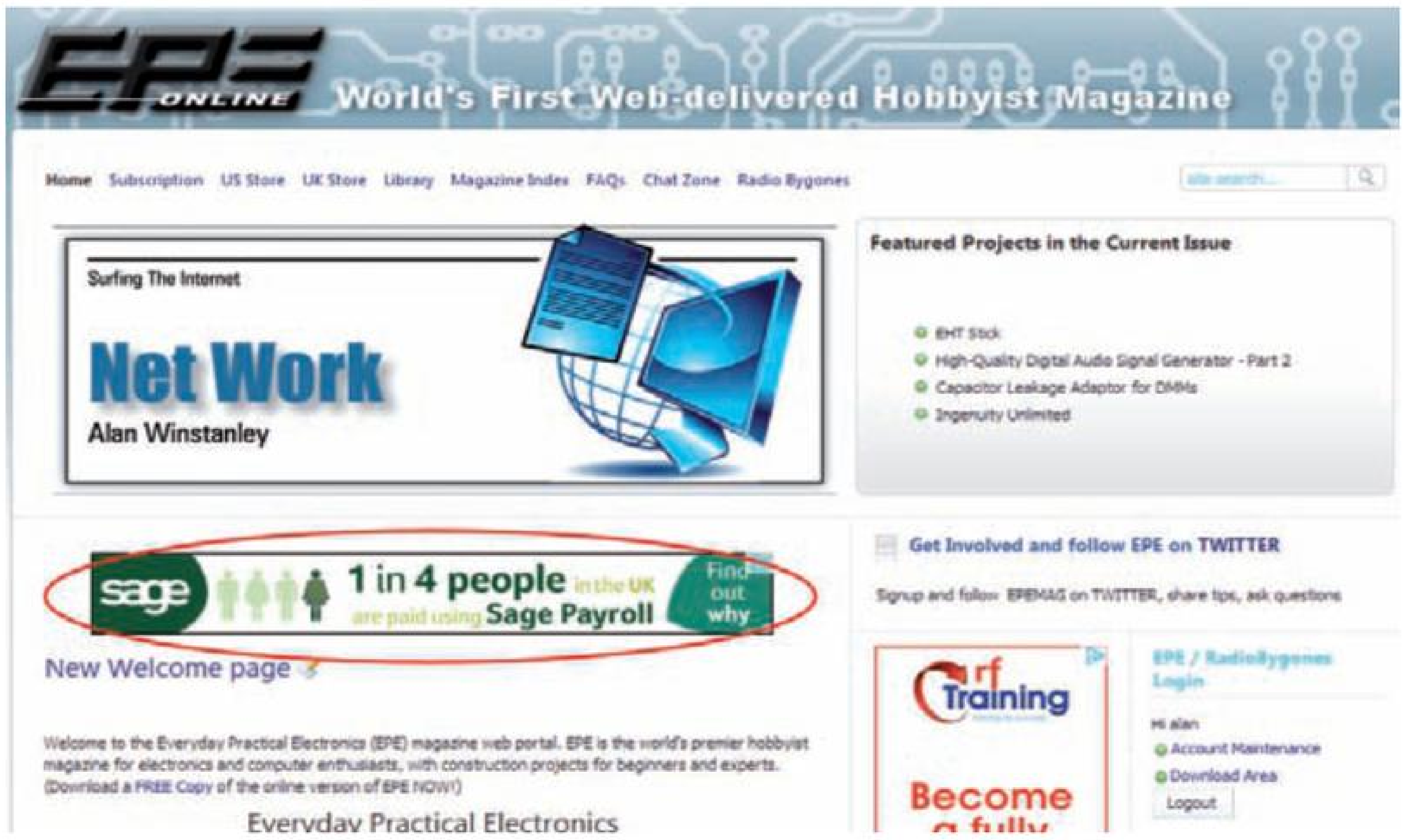
NET WORK

by Alan Winstanley

Keep on trucking...

AN acquaintance who phoned me made the passing observation that he was interested in buying a new 4x4 truck, so he surfed over to the Toyota website to learn more about their latest vehicles. Now, he explained, whenever he looks on any website he is confronted with adverts for Toyota! I explained that he is probably looking at adverts served up by Google, the world's largest online admonger, and that his visit to Toyota probably resulted in a 'cookie' being downloaded onto his PC as evidence of his surfing.

The same thing happened to me – a month or two ago, I recounted in *Net Work* the problem I had with HMRC's free payroll program causing problems at a company's year end, and every time I visited a website (including our own) I was eye-bashed by Google adverts for Sage accounting software.



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- High-Quality Digital Audio Signal Generator - Part 2
- Capacitor Leakage Adaptor for DMMs
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An online ad. for Sage payroll appeared on EPEMag's website soon after the author visited the Sage website itself

Artful cookies

Cookies are innocuous text files that cannot identify you personally, but they can be designed to track a web user's surfing pattern (see *Net Work* April 2012). One of Google's advertising programs is called 'AdSense', and it uses a form of artificial intelligence to figure out what the contents of a webpage are all about. Any Google Ads that are hosted on the same web page are then served up in the same context: if you browse a webpage all about soldering irons then any Google adverts broadly relate to the same topic.

Google Adsense is effectively an enormous auction, because a number of criteria are used to determine which advert appears at the top of a list where they stand more chance of being clicked on than the adverts underneath. The chances are that anyone googling for a product or topic will find a webpage containing relevant advertisements thanks to Google's ad-sensing campaigns. The same is true of Google Gmail, which 'reads' your emails and tries to display some adverts that are relevant to the subject matter.

Things have moved on, though, and online advertising is now a huge and lucrative science, often over-analysed and intensely analytical in nature. A surfer's activity can be tracked ever more closely in order to build up their profiles and hopefully target them with more personalised adverts. Hence, my friend saw Toyota adverts online everywhere he went, while I saw banner adverts for Sage software instead.

The term 'behavioural advertising' or 'interest-based' ads applies to those ads that are displayed based on users' recent surfing over a number of websites. It's a moot point, though, whether someone actively googling for information on soldering irons will respond more positively at the time to adverts selling Toyota trucks: the chances are that they're in the market for soldering irons not 4×4s, but Google's advertising machinery can look at your history and try to sell you a Toyota or Sage accounting software anyway.

You can learn more or try to opt out of this type of behavioural marketing by visiting the beta service at: **www.aboutads.info/choices**, but the coverage is relatively narrow. The general claim that cookies cannot identify you personally is looking increasingly disingenuous, for the Internet's admongers are becoming highly skilled at profiling you, and seem to know pretty much everything else about you except your name.

Not so anonymous

Facebook is the omnipresent but deceptively complex social networking site that plays a large role in many people's everyday lives. I still consider that many inexperienced Internet users are like lambs to the slaughter as far as covering their steps, or protecting their privacy on Facebook are concerned. I remain critical of Facebook's maze of privacy settings that need studying intensively to appreciate all their implications first, before anyone pours their heart out online.

A recent case that I was involved with illustrates how public 'anonymous' information on Facebook and Google was used to locate an individual. I was asked to help a company that was the victim of an adverse anonymous Google review that was both highly damaging and untrue.

By logging into Google Maps, (**maps.google.co.uk/etc**), local businesses can 'claim' their business ID on a map and upload information about themselves which can be viewed online. Unfortunately, this opens up the prospect of receiving irresponsible or damaging reviews and star ratings posted by customers (or non-customers – anyone with a Google account can post a 'review'). It's often a kid's playground.

I knew from experience that asking Google to remove off-topic or malicious reviews would probably be a waste of time: I've tried it before without success. However, a few days later the same anonymous user posted another Google review, this time a glowing report of a rival business which was written in a particular style. We located the rival firm's Facebook page, where the identical style was evident in another post, this time written under a different username.

It was easy to put two and two together. The poster's own Facebook page (soon found) gave clues about their interests, that alluded to their original Google ID. Their Facebook ID contained another clue, so the firm's records were searched to find anyone with a similar sounding name and – bingo – the person was pinpointed within 15 seconds. A photo on Facebook helped confirm that our conclusion was correct.

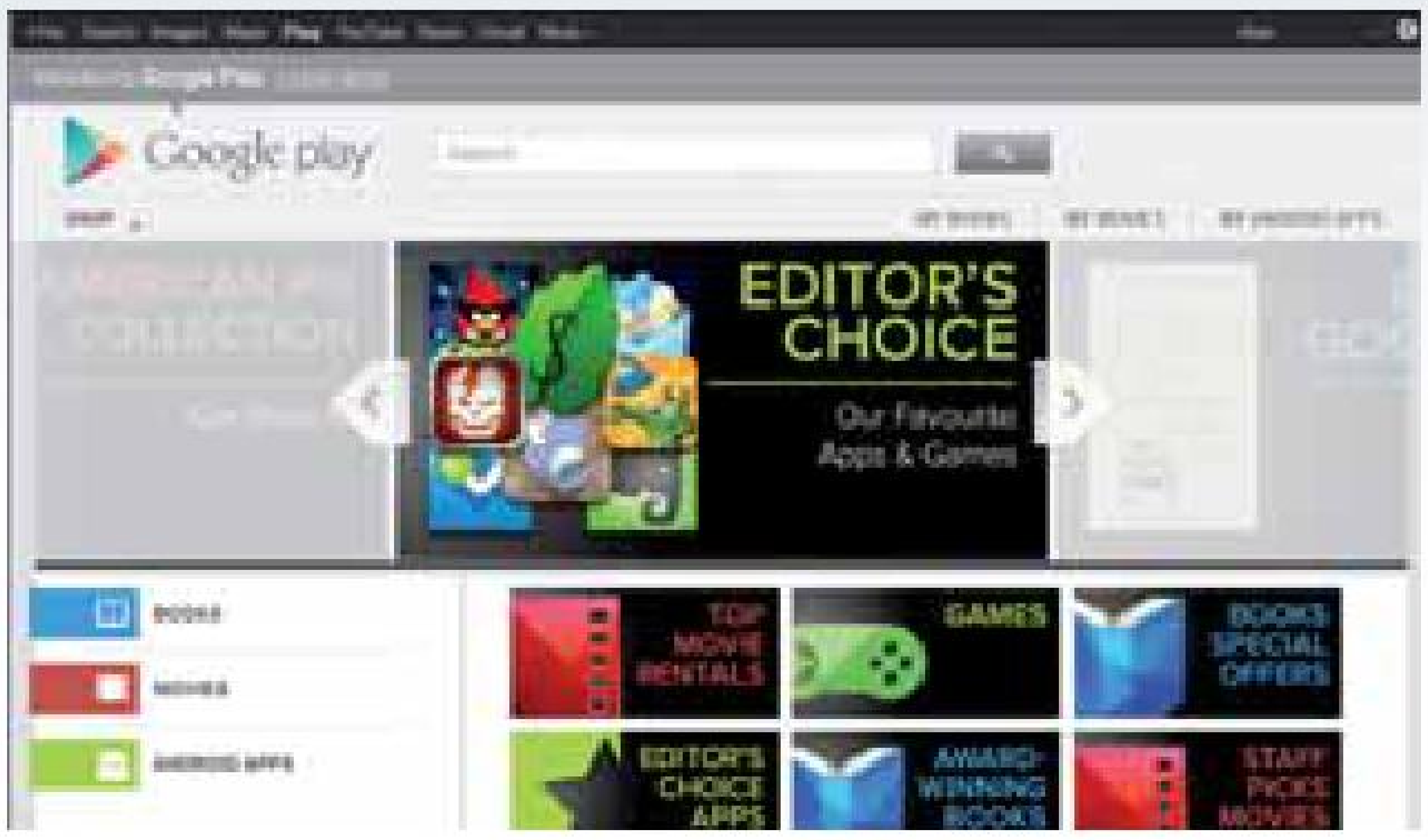
As the user had volunteered their email address to the business at the time, this granted the firm permission to contact them – which is precisely what happened. I can only imagine the scene when the 'anonymous' user, hiding behind a Google ID, received a request to remove the damaging part of their review. The point is, readers, that it was possible to join the dots and locate a naïve Internet user within minutes, merely by using publically-available information on Facebook and Google Local.

The Internet is crammed full of low-grade noise that detracts from the net's usefulness, and while personal opinions are entirely subjective, posting 'reviews' prominently on the Internet carries responsibilities to ensure that facts are portrayed accurately. It is unfortunate that so much childish and thoughtless behaviour online – such as posting phoney reviews – can cause innocent businesses so much damage. In more serious cases it becomes necessary to 'go legal' to force user information to be released, a situation when the only real winners are the lawyers.

Google Playtime

A few decades ago, when VHS home video players were all the rage, we could rent movies from a video store in town, or send away by mail order and wait for a movie to arrive in the post a week or two later. It seems there are myriad ways of watching a movie these days, with traditional DVD rental and broadband-delivered options available to us. The day will eventually come where cinemagoers will watch 3D movies beamed by satellite straight from Hollywood, but until then we can choose from a number of services that can deliver a movie on to our broadband-connected TV, PC, games console, tablet or phone. Your ISP may offer a bundled entertainment package and Sky+, Netflix, Amazon's Lovefilm and similar services offer the same.

Google has finally arrived in this market with its new 'Play' portal for distributing movies, ebooks, games and Android apps online. Far more than a search engine, Google offers Google Drive online storage, Image search, Google Maps, Youtube videos and Gmail. The key to accessing Google's services lies in the black navigation bar along the top of the web browser window – see screen grab – the design of which changes periodically or disappears altogether when Google experiments with other formats. Today, if you log into Google Gmail, for example, a black bar includes a discrete 'Play' menu item, or you can go directly to: **play.google.com** to access their latest entertainment portal.



Google Play is the latest portal to offer movies, ebooks and Android Apps. Note the menu bar at the top. Visit *play.google.com* for details

You can 'rent' movies for £2 to £3 or so, and you have 48 hours of 'rental active period' (viewing time) available within 30 days of purchase (the 'rental grant' period). Since a gallon of petrol costs £6 and only lasts half an hour, such movie rental costs are attractive. The interface is very straightforward to use, in keeping with Google's minimalist approach. A Google Wallet account is required for payment, bringing with it the need to be vigilant about your security.

ebooks are purchased individually (US, Australia, UK and Canada only) and can be read directly within a javascript-enabled web browser, Android phone, iPhone, iPad and many popular ereaders. Books are stored in the cloud on your 'My Purchased eBooks' digital shelf, so that if you lose your data you can re-sync to your collection of books.

Google offers three books free (*Alice's Adventures in Wonderland*, *Pride and Prejudice*, and *Great Expectations*) to help get you started: search Google Play for titles and filter the results for 'free books': I accessed Alice's (Illustrated) Adventures within a few seconds via a web browser. Other titles may be subject to DRM (Digital Rights Management), and plenty of online help is available to get you going.

Also on offer at Google Play, is a range of Android Apps for your phone or tablet. Perhaps one of the keenly-priced 7-inch or 10-inch Android devices highlighted in previous columns might be the perfect introduction to tablets, at a fraction of the cost of an iPad.

That's all for this month's *Net Work*. A special *Net Work* section is now available in the *EPE Chat Zone* for Internet related topics (see **www.chatzones.co.uk**). You can visit the writer's website at: **www.alanwinstanley.com** and **www.epemag.net**, or contact Alan at **alan@epemag.demon.co.uk**. You can also share your views with the editor at **editorial@wimborne.co.uk**.

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All letters quoted here have previously been replied to directly

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☆ LETTER OF THE MONTH ☆

Jump Start feedback

Dear editor

The *Jump Start* article by Mike and Richard Tooley in the May edition of *EPE* was of interest to me because of the particular application; ie, detection of water/moisture. Using the change of resistance between two probes is an obvious technique, and it reminded me of some work I did years ago for a company in the field of water leak detection and location. Measurement of the resistance between two probes produced some strange results in that the resistance appeared to be voltage dependent (at low voltages), time dependent when a step voltage was applied, and exhibited a polarity effect.

Clearly, major factors are the quantity and type of impurities in the water, as these determine conduction and electrochemical effects (along with the metal of the electrodes) which are the probable cause of the effects mentioned. If the design uses a DC test for detection (rather than for measurement) then these effects are not too critical and will be accounted for in the setting of the 'trip' level.

Although resistance measurement is the obvious way to detect water, it is not the only way. My measurements on tap water with differing metals for the 'probes' have shown that a significant voltage is generated between a brass electrode and a galvanised-steel electrode – over 0.7V with Yorkshire tap water!

This 'battery' voltage effect can be used to measure the presence of liquid water between the electrodes (taking care to get the polarity correct). The voltage is low, but sufficient to turn on a bipolar transistor.

However, using an ADC in a processor to measure the voltage gives a more flexible system, since the 'trip' voltage can be adjusted with the probes terminated with a small shunt capacitor to prevent interference pick-up triggering the system.

A further possible alternative is to use a pulse technique to detect the presence of water between two probes by measurement of a time/voltage difference. It will clearly be more complicated than the simple DC techniques described earlier, but there may be some subtle advantage somewhere.

Ken Naylor, by email

Matt Pulzer replies:

Ken, many thanks for your observations and clever alternatives for moisture detection. Jump Start *is very much aimed at beginners, hence the simple (but effective) techniques used, but it's great to hear about more advanced approaches. Clearly, there really is 'something in the water' in Yorkshire!*

Humax file transfer success!

Dear editor

I'm writing to tell you how useful the Jan 2012 *Letter of the Month* was for me. It was written by Les Hadden and concerned file transfer from a Humax HDR-FOX T2 PVR to a PC.

I recently purchased one of these PVRs, and needed to know how to transfer files to my netbook for viewing while I'm away from home. The excellent description of the procedures and software provided by Les has saved me a huge amount of time. I've bought a 16GB USB memory stick and formatted it to ext3. Now – using the software described by Les – I can transfer the files on to my netbook hard drive. Windows media player takes care of the playback.

It is worth mentioning that when copying a recording to the USB memory stick, the Humax sends other files as well as the wanted .ts MPEG-2 file (ie, .hmt .nts .thm). I have found that these other files can be discarded with no ill effect.

So, thanks again to Les and to *EPE* for keeping us all informed!

Russell Tribe, by email

Matt Pulzer replies:

We are glad to have been able to pass on Les' great tips via Readout.

Desoldering

Dear editor

I read Alan Winstanley's great article on soldering (**www.epemag.wimborne.co.uk/solderfaq.htm#temp**) and it has prompted a question. I'm a novice, trying to replace a small 330μF 10V cap on a PCB used in a printer.

When I was attempting to desolder the old stubborn capacitor, I must have overheated the copper pad, as it now appears to be lifting and curling at the corners. There aren't any traces connected to the pad on its side of the board, but the hole is still closed with the old solder after I finally managed to remove the bad capacitor.

I'm concerned about heating this any more than I have to, and I'm trying to figure out the best way to get the new cap installed. Do you think it's worth trying my luck at desoldering again? Or should I try to heat the board just enough to liquify the existing solder, while pushing the leads for the new cap through the holes? Or, as an alternative last-ditch effort, would it be best to find a small drill bit to bore through the thin layer of old hardened solder?

I'd appreciate any insight you have for me, thanks!!

James, by email

Alan Winstanley replies:

It's a bit hard to say without seeing your PCB. I wonder if it's a multi-layer board containing a sandwich of conductors within the board, or, if it's a plated-through hole (which are impossible to desolder). Both of these risk being damaged if you try to drill out the solder.

I would try to heat the board just enough to liquify the existing solder while pushing the leads for the new cap through the holes. Or, I'd try to push a steel wire through (it won't stick to the solder).

You can send me a photo if you like.

Alan Winstanley, EPE online editor

Readers can contact Alan by email at: alan@epemag.demon.co.uk

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Max's Cool Beans

By Max The Magnificent

Mechanical computer

Recently, I ran across an interesting article on the *BBC Technology* website that set my creative juices flowing (**www.bbc.co.uk/news/technology-12893426**).

One item that really captured my attention was a mechanical computer that is programmed by the movement of ball bearings. If you've learnt anything about computer history, you will recognise this as a Turing machine (**http://en.wikipedia.org/wiki/Turing_machine**) just like the one Alan Turing (1912 – 1954) envisaged and explored in his mathematical paper that kicked off the computer age.

A Turing machine is something that uses very simple rules to perform its computations. As originally conceived, Turing machines are not physical objects, but mathematical ones. Having said this, lots of folks have constructed some jolly interesting physical realisations. For example, after the BBC article had tweaked my interest, I started bouncing around the Internet looking for some other cool examples. As part of this, I found a Lego Turing machine (**http://youtu.be/cY-w2ewoO6c4**), a scrap metal Turing machine (**http://youtu.be/40DkJ9vt5CI**), and a truly incredible Turing machine, which was created by a guy called Mike Davey (**http://youtu.be/E3keLeMwfHY**).

Table 1: High-level representation of a generic Turing machine

Current State	Tape Symbol	Write Operation	Move Operation	Next State
S_{now}	--	--, B, 0, 1	N, L, R	S_{new}
	B	--, B, 0, 1	N, L, R	S_{new}
	0	--, B, 0, 1	N, L, R	S_{new}
	1	--, B, 0, 1	N, L, R	S_{new}

The concept behind the original (virtual) Turing machine was to have an infinite strip of paper tape. Since Mike could not find the infinitely long tape required for the project, his solution was to use 1,000 feet of white 35mm film leader and a dry erase marker. As you will see in the above video, the result is absolutely incredible.

Around this point, I started to think about building my own machine, and I was really getting carried away by all of this, so it was a bit awkward when I suddenly came to the realisation that I no longer had a clue as to how these little rascals actually worked. This was one of those occasions where I did know this stuff once, but the nitty-gritty details have faded from my mind as the years have gone.

Thus, I decided to work things out from first principles as follows… In his original thought experiment, Turing imagined a machine that is 'looking at' a paper tape that is infinitely long in each direction. The machine can read the value on the paper tape at its current location (this value could be a blank, or a '0', or a '1'). The machine can modify this value if it wishes, and it can then move the tape one position to the left or right.

The way the Turing machine works is as a state machine. Basically, you decide what program you wish to perform and you create a state machine to implement it. On this basis, we can have as many states as we wish – let's call them S0, S1, S2… Sn. The actions our machine can perform are depicted in Table 1.

We commence in some current state, S_{now} (one of our S0, S1... states), which will be stored in a set of state variable registers. The machine reads the value on the tape at the current position. This value may be B (blank), 0, or 1; the '–' entry in this column of the table indicates that we may simply not care what the value on the tape is.

For each of the different possible existing values on the tape, we may decide to write a new value at this position. This new value may be B (Blank, which means to clear this location), 0, or 1; alternatively, we may not wish to write anything at this time, which equates to the '–' entries in this column of the table.

Next, we perform a move operation N (none), L (one place left), or R (one place right). Finally, we load our state variables with some new state, S_{new} (one of our S0, S1... states), which could be different for each row in the table, and then we do the whole thing again. Of course, Table 1 offers just a high-level generic view. For a real implementation we would expand the table out to explicitly describe the actions of each state and transition between states.

Just imagine

The thing is, when it comes to Turing machines, you are limited only by your imagination. As opposed to having a fixed machine with movable media (the paper tape), you can have a machine that moves over fixed media; for example, a small electric train that moves back and forth along a track, making marks or picking up/putting down objects (like ball bearings) as it goes.

Why restrict ourselves to one-dimensional Turing machines, by which I mean ones using one-dimensional media like paper tape? Suppose we had a two-dimensional machine based on a large checkered board (like a super-size chess board). We could have a little robot that could move square-by-square, left and right, and forward and backward, picking up and putting down black and white pebbles. (We could extend this by letting the robot move diagonally and/or using colored pebbles.)

We could even move into three dimensions ... I'm visualising a scaffolding-type structure of small cubes (say three inches on a side) with a little robot crawling around (forward, backward, left, right, up, down) somehow reading the 'value' associated with each cube and writing a new value if it wished.

I tell you, my head is currently bursting with ideas, some of which I'm sure I will relate in future columns. In the meantime, if you've built your own Turing machine or have any ideas for a possible *Cool Beans* implementation, email me at: **max@CliveMaxfield.com**

Until next time, have a good one!

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ELECTRONICS TEACH-IN 2 CD-ROM USING PIC MICROCONTROLLERS A PRACTICAL INTRODUCTION

This *Teach-In* series of articles was originally published in *EPE* in 2008 and, following demand from readers, has now been collected together in the *Electronics Teach-In 2* CD-ROM.

The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

Also included are 29 *PIC N' Mix* articles, also republished from *EPE*. These provide a host of practical programming and interfacing information, mainly for those that have already got to grips with using PIC microcontrollers. An extra four part beginners guide to using the C programing language for PIC microcontrollers is also included.

The CD-ROM also contains all of the software for the *Teach-In 2* series and *PIC N' Mix* articles, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

The Microchip items are: MPLAB Integrated Development Environment V8.20; Microchip Advance Parts Selector V2.32; Treelink; Motor Control Solutions; 16-bit Embedded Solutions; 16-bit Tool Solutions; Human Interface Solutions; 8-bit PIC Microcontrollers; PIC24 Micrcontrollers; PIC32 Microcontroller Family with USB On-The-Go; dsPIC Digital Signal Controllers.

CD-ROM **Order code ETI2 CD-ROM** **£9.50**

FREE CD-ROM

ELECTRONICS TEACH-IN 3

The three sections of this book cover a very wide range of subjects that will interest everyone involved in electronics, from hobbyists and students to professionals. The first 80-odd pages of Teach-In 3 are dedicated to *Circuit Surgery*, the regular *EPE* clinic dealing with readers' queries on various circuit design and application problems – everything from voltage regulation to using SPICE circuit simulation software.

The second section – *Practically Speaking* – covers the practical aspects of electronics construction. Again, a whole range of subjects, from soldering to avoiding problems with static electricity and indentifying components, are covered. Finally, our collection of *Ingenuity Unlimited* circuits provides over 40 circuit designs submitted by the readers of *EPE*.

The free cover-mounted CD-ROM is the complete *Electronics Teach-In 1* book, which provides a broad-based introduction to electronics in PDF form, plus interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial), together with simulations of the circuits in the Teach-In 1 series, plus Flowcode (a limited version) a high level programming system for PIC microcontrollers based on flowcharts.

The Teach-In 1 series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC. There is also a MW/LW Radio project in the series. The contents of the book and Free CD-ROM have been reprinted from past issues of *EPE*.

160 pages **Order code ETI3** **£8.50**

Book and CD-ROMs **Order code ETIBUNDLE** Bundle Price **£14.00**

NEW

ELECTRONICS TEACH-IN 4

FREE CD-ROM

ELECTRONICS TEACH-IN 4

A Broad-Based Introduction to Electronics plus FREE CD-ROM

The Teach-In 4 book covers three of the most important electronics units that are currently studied in many schools and colleges. These include, Edexcel BTEC level 2 awards and the electronics units of the new Diploma in Engineering, Level 2.

The Free cover-mounted CD-ROM contains the full Modern Electronics Manual, worth £29.95. The Manual contains over 800 pages of electronics theory, projects, data, assembly instructions and web links.

A package of exceptional value that will appeal to all those interested in learning about electronics or brushing up on their theory, be they hobbyists, students or professionals.

Available NOW – see page 24 in this issue for details

The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page.

FOR A FURTHER SELECTION OF BOOKS AND CDROMS SEE THE UK SHOP ON OUR WEBSITE

www.epemag.com

All prices include UK postage

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COMPUTING AND ROBOTICS

WINDOWS XP EXPLAINED

N. Kantaris and P. R. M. Oliver

If you want to know what to do next when confronted with Microsoft's Windows XP screen, then this book is for you. It applies to both the Professional and home editions.

The book was written with the non-expert, busy person in mind. It explains what hardware requirements you need in order to run Windows XP successfully, and gives an overview of the Windows XP environment.

The book explains: How to manipulate Windows, and how to use the Control Panel to add or change your printer, and control your display; How to control information using WordPad, notepad and paint, and how to use the Clipboard facility to transfer information between Windows applications; How to be in control of your filing system using Windows Explorer and My Computer; How to control printers, fonts, characters, multimedia and images, and how to add hardware and software to your system; How to configure your system to communicate with the outside world, and use Outlook Express for all your email requirements; how to use the Windows Media Player 8 to play your CDs, burn CDs with your favourite tracks, use the Radio Tuner, transfer your videos to your PC, and how to use the Sound Recorder and Movie Maker; How to use the System Tools to restore your system to a previously working state, using Microsoft's Website to update your Windows setup, how to clean up, defragment and scan your hard disk, and how to backup and restore your data; How to successfully transfer text from those old but cherished MS-DOS programs.

264 pages **Order code BP514** **£7.99**

INTRODUCING ROBOTICS WITH LEGO MINDSTORMS

Robert Penfold

Shows the reader how to build a variety of increasingly sophisticated computer controlled robots using the brilliant Lego Mindstorms Robotic Invention System (RIS). Initially covers fundamental building techniques and mechanics needed to construct strong and efficient robots using the various "click-together" components supplied in the basic RIS kit. explains in simple terms how the "brain" of the robot may be programmed on screen using a PC and "zapped" to the robot over an infra-red link. Also, shows how a more sophisticated Windows programming language such as Visual BASIC may be used to control the robots.

Detailed building and programming instructions provided, including numerous step-by-step photographs.

288 pages + Large Format **Order code BP901** **£14.99**

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS – Robert Penfold

Covers the Vision command system

Shows the reader how to extend the capabilities of the brilliant Lego Mindstorms Robotic Invention System (RIS) by using lego's own accessories and some simple home constructed units. You will be able to build robots that can provide you with 'waiter service' when you clap your hands, perform tricks, 'see' and avoid objects by using 'bats radar', or accurately follow a line marked on the floor. Learn to use additional types of sensors including rotation, light, temperature, sound and ultrasonic and also explore the possibilities provided by using an additional (third) motor. For the less experienced, RCX code programs accompany most of the featured robots. However, the more adventurous reader is also shown how to write programs using Microsoft's VisualBASIC running with the ActiveX control (Spirit.OCX) that is provided with the RIS kit.

Detailed building instructions are provided for the featured robots, including numerous step-by-step photographs. The designs include rover vehicles, a virtual pet, a robot arm, an 'intelligent' sweet dispenser and a colour conscious robot that will try to grab objects of a specific colour.

298 pages **Order code BP902** **£14.99**

THE PIC MICROCONTROLLER YOUR PERSONAL INTRODUCTORY COURSE – THIRD EDITION John Morton

Discover the potential of the PIC microcontroller through graded projects – this book could revolutionise your electronics construction work!

A uniquely concise and practical guide to getting up and running with the PIC Microcontroller. The PIC is one of the most popular of the microcontrollers that are transforming electronic project work and product design.

Assuming no prior knowledge of microcontrollers and introducing the PICs capabilities through simple projects, this book is ideal for use in schools and colleges. It is the ideal introduction for students, teachers, technicians and electronics enthusiasts. The step-by-step explanations make it ideal for self-study too: this is not a reference book – you start work with the PIC straight away.

The revised third edition covers the popular reprogrammable Flash PICs: 16F54/16F84 as well as the 12F508 and 12F675.

270 pages **Order code NE36** **£25.00**

INTRODUCTION TO MICROPROCESSORS AND MICROCONTROLLERS – SECOND EDITION

John Crisp

If you are, or soon will be, involved in the use of microprocessors and microcontrollers, this practical introduction is essential reading. This book provides a thoroughly readable introduction to microprocessors and micrcontrollers. Assuming no previous knowledge of the subject, nor a technical or mathematical background. It is suitable for students, technicians, engineers and hobbyists, and covers the full range of modern micros.

After a thorough introduction to the subject, ideas are developed progressively in a well-structured format. All technical terms are carefully introduced and subjects which have proved difficult, for example 2's complement, are clearly explained. John Crisp covers the complete range of microprocessors from the popular 4-bit and 8-bit designs to today's super-fast 32-bit and 64-bit versions that power PCs and engine management systems etc.

222 pages **Order code NE31** **£29.99**

EASY PC CASE MODDING

R.A Penfold

Why not turn that anonymous grey tower, that is the heart of your computer system, into a source of visual wonderment and fascination. To start, you need to change the case or some case panels for ones that are transparent. This will then allow the inside of your computer and it's working parts to be clearly visible.

There are now numerous accessories that are relatively inexpensive and freely available, for those wishing to customise their PC with added colour and light. Cables and fans can be made to glow, interior lights can be added, and it can all be seen to good effect through the transparent case. Exterior lighting and many other attractive accessories may also be fitted.

This, in essence, is case modding or PC Customising as it is sometimes called and this book provides all the practical details you need for using the main types of case modding components including:- Electro luminescent (EL) 'go-faster' stripes: Internal lighting units: Fancy EL panels: Data cables with built-in lighting: Data cables that glow with the aid of 'black' light from an ultraviolet (UV) tube: Digital display panels: LED case and heatsink fans: Coloured power supply covers.

192 pages + CD-ROM **Order code BP542** **£8.99**

ROBOT BUILDERS COOKBOOK

Owen Bishop

This is a project book and guide for anyone who wants to build and design robots that work first time.

With this book you can get up and running quickly, building fun and intriguing robots from step-by-step instructions. Through hands-on project work, Owen introduces the programming, electronics and mechanics involved in practical robot design-and-build. The use of the PIC microcontroller throughout provides a painless introduction to programming – harnessing the power of a highly popular microcontroller used by students, hobbyists and design engineers worldwide.

Ideal for first-time robot builders, advanced builders wanting to know more about programming robots, and students tackling microcontroller-based practical work and labs.

The book's companion website at http://books.elsevier.com/companions/9780750665568 contains: downloadable files of all the programs and subroutines; program listings for the Quester and the Gantry robots that are too long to be included in the book.

366 pages **Order code NE46** **£26.00**

THEORY AND REFERENCE

GETTING THE MOST FROM YOUR MULTIMETER

R. A. PenfoldM

This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.

In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

96 pages **Order code BP239** **£5.49**

OSCILLOSCOPES – FIFTH EDITION

Ian Hickman

Oscilloscopes are essential tools for checking circuit operation and diagnosing faults, and an enormous range of models are available.

This handy guide to oscilloscopes is essential reading for anyone who has to use a 'scope for their work or hobby; electronics designers, technicians, anyone in industry involved in test and measurement, electronics enthusiasts . . . Ian Hickman's review of all the latest types of 'scope currently available will prove especially useful for anyone planning to buy – or even build – an oscilloscope.

The contents include a description of the basic oscillscope; Advanced real-time oscilloscope; Accessories; Using oscilloscopes; Sampling oscilloscopes; Digital storage oscilloscopes; Oscilloscopes for special purposes; How oscillocopes work (1): the CRT; How oscilloscopes work (2): circuitry; How oscilloscopes work (3): storage CRTs; plus a listing of Oscilloscope manufacturers and suppliers.

288 pages **Order code NE37** **£36.99**

UNDERSTANDING ELECTRONIC CONTROL SYSTEMS

Owen Bishop

Owen Bishop has produced a concise, readable text to introduce a wide range of students, technicians and professionals to an important area of electronics. Control is a highly mathematical subject, but here maths is kept to a minimum, with flow charts to illustrate principles and techniques instead of equations.

Cutting edge topics such as microcontrollers, neural networks and fuzzy control are all here, making this an ideal refresher course for those working in Industry. Basic principles, control algorithms and hardwired control systems are also fully covered so the resulting book is a comprehensive text and well suited to college courses or background reading for university students.

The text is supported by questions under the headings Keeping Up and Test Your Knowledge so that the reader can develop a sound understanding and the ability to apply the techniques they are learning.

228 pages **Order code NE35** **£36.99**

A BEGINNER'S GUIDE TO TTL DIGITAL ICs

R. A. Penfold

This book first covers the basics of simple logic circuits in general, and then progresses to specific TTL logic integrated circuits. The devices covered include gates, oscillators, timers, flip/flops, dividers, and decoder circuits. Some practical circuits are used to illustrate the use of TTL devices in the "real world".

142 pages **Order code BP332** **£5.45**

PRACTICAL ELECTRONICS CALCULATIONS AND FORMULAE

F. A. Wilson, C.G.I.A., C.Eng., F.I.E.E., F.I.E.R.E., F.B.I.M.

Bridges the gap between complicated technical theory, and "cut-and-tried" methods which may bring success in design but leave the experimenter unfulfilled. A strong practical bias – tedious and higher mathematics have been avoided where possible and many tables have been included.

The book is divided into six basic sections: Units and Constants, Direct-Current Circuits, Passive Components, Alternating-Current Circuits, Networks and Theorems, Measurements.

256 pages **Order code BP53** **£6.99**

MICROCONTROLLER COOKBOOK

Mike James

The practical solutions to real problems shown in this cookbook provide the basis to make PIC and 8051 devices really work. Capabilities of the variants are examined, and ways to enhance these are shown. A survey of common interface devices, and a description of programming models, lead on to a section on development techniques. The cookbook offers an introduction that will allow any user, novice or experienced, to make the most of microcontrollers.

240 pages **Order code NE26** **£36.99**

FULL COLOUR COMPUTING BOOKS

HOW TO FIX YOUR PC PROBLEMS

R.A. Penfold

What do you do when your laptop or desktop stops working properly. Do you panic, try to find the answer on the page of fault finding tips you may find at the back of the manufacturers manual. Or do you spend hours trying to get through to a telephone helpline or waste even more time waiting for an email reply from a helpdesk.

Well help is now at hand! This book will assist you in identifying the type of problem, whether it's hardware, software or a peripheral that is playing up? Once the fault has been identified, the book will then show you how to go about fixing it. This book uses plain English and avoids technical jargon wherever possible. It is also written in a practical and friendly manner and is logically arranged for easy reference.

The book is divided into four main sections and among the many topics covered are: Common problems with Windows Vista operating system not covered in other chapters. Also covers to a lesser extent Windows XP problems. Sorting out problems with ports, peripherals and leads. Also covers device drivers software and using monitoring software. Common problems with hard disc drives including partitioning and formatting a new drive. Using system restore and recovering files. Also covers CD-ROM and Flash drives. Common problems with sound and video, including getting a multi-speaker system set up correctly.

An extremely useful addition to the library of all computer users, as you never know when a fault may occur!

Printed in full colour on high quality non-refective paper

128 pages **Order code BP705** **£8.49**

AN INTRODUCTION TO WINDOWS VISTA

P.R.M. Oliver and N. Kantarris

If you have recently bought a new desktop or laptop it will almost certainly have Windows as its operating system. Windows Vista manages the available resource of a computer and also 'controls' the programs that run on it.

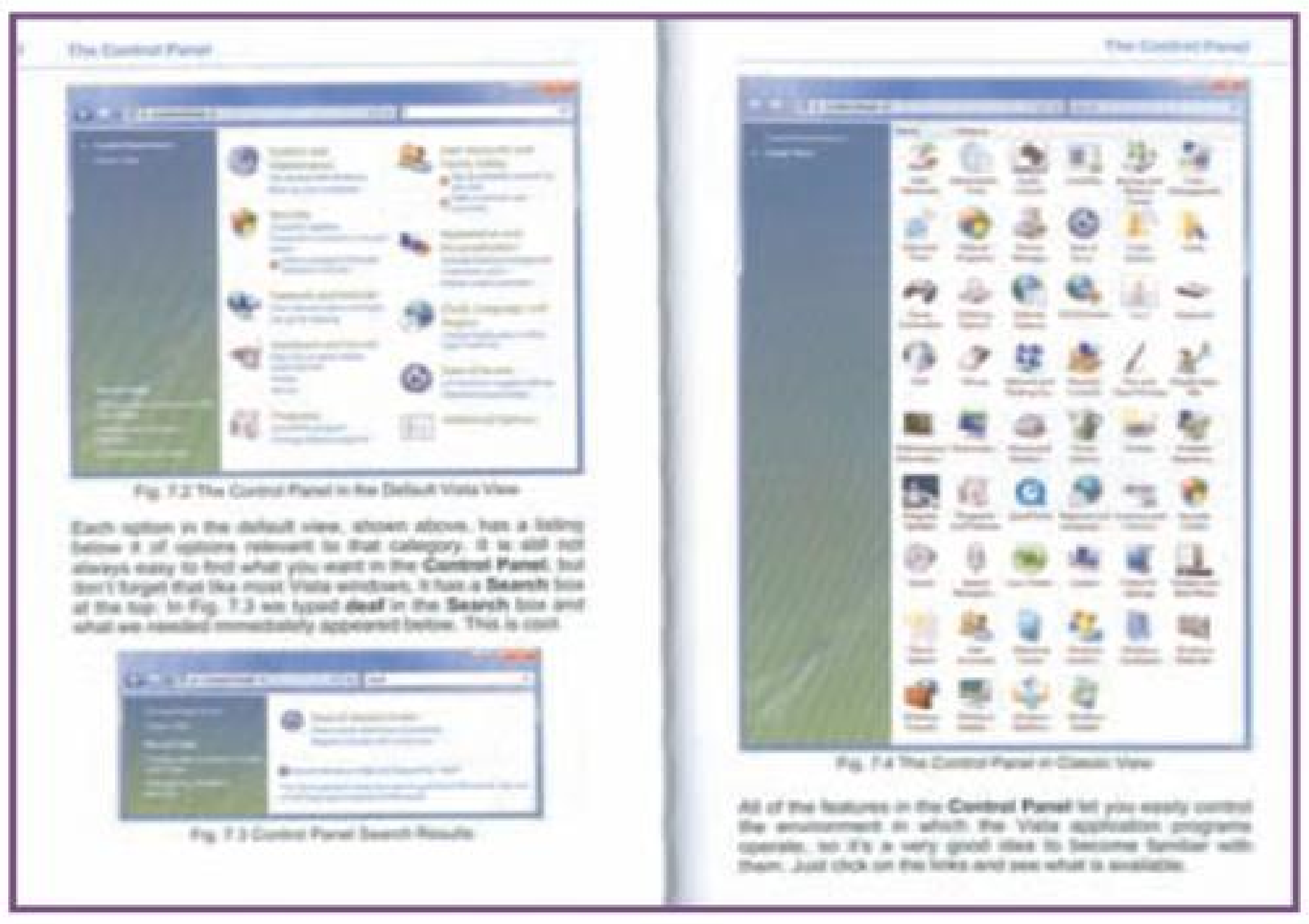
To get the most from your computer, it is important that you have a good understanding of Vista. This book will help you acheive just that. It is written in a friendly and practical way and is suitable for all age groups from youngsters to the older generation. It has been assumed that Vista is installed and running on your computer.

Among the numerous topics explained are: The Vista environment with its many windows. How to organise your files, folders and photos. How to use Internet Explorer for your web browsing. How to use Microsoft Mail for your emails. How to control your PC and keep it healthy. How to use Vista's Accessibility features if you have poor eye sight or difficulty in using the keyboard or mouse. And much more besides....

With the help of this book you will easily and enjoyably gain a better understanding of Microsoft's amazing Windows Vista operating system.

Printed in full colour on high quality non-refective paper

120 pages **Order code BP703** **£8.49**



COMPUTING WITH A LAPTOP FOR THE OLDER GENERATION

R.A. Penfold

Laptop computers have rapidly fallen in price, increased in specification and performance and become much lighter in weight. They can be used practically anywhere, then stored away out of sight. It is therefore, not surprising that laptop sales now far exceed those of desktop machines and that they are increasingly becoming the machine of choice for the older generation.

You may want to use your laptop as your main computer or as an extra machine. You may want to use your laptop on the move, at home, at work or on holiday. Whatever your specific requirements are, the friendly and practical approach of this book will help you to understand and get the most from your laptop PC in an easy and enjoyable way. It is written in plain English and wherever possible avoids technical jargon.

Among the many topics covered are: Choosing a laptop that suits your particular needs. Getting your new computer set up properly. Customising your computer so that it is optimised for your particular needs. Setting up and dealing with user accounts. Using the Windows 'Ease of Access Center'. Optimising the life and condition of your battery. Keeping the operating system and other software fully up-to-date. Troubleshooting common problems. Keeping your computer and data safe and secure. And much more besides...

Even though this book is written for the older generation, it is also suitable for anyone of any age who has a laptop or is thinking of buying one. It is written for computers that use Windows Vista as their operating system but much will still apply to Windows XP machines. Printed in full colour on high quality non-refective paper

120 pages **Order code BP702** **£8.49**

AN INTRODUCTION TO EXCEL SPREADSHEETS

Jim Gatenby

The practical and friendly approach of this book will help newcomers to easily learn and understand the basics of spreadsheets. This book is based on Microsoft's Excel 2007 spreadsheet, but much of the book will still apply to earlier versions of Excel. The book is written in plain English, avoiding technical and mathematical jargon and all illustrations are in full colour. It is suitable for all age groups from youngsters to the older generation.

Among the many topics explained are how to: Install the software. Use the exciting new features of Excel 2007. Create and use a spreadsheet. Enter, edit and format text, numbers and formulae. Insert and delete columns and rows. Save and print a spreadsheet. Present the information on a spreadsheet as a graph or chart. Manage and safeguard Excel files on disc. Use Excel as a simple database for names and addresses.

This book will help you to quickly gain confidence and get to grips with using spreadsheets. In fact, you will wonder how you ever managed without them.

Printed in full colour on high quality non-reflective paper.

118 pages **Order code BP701** **£8.49**

AN INTRODUCTION TO DIGITAL PHOTOGRAPHY WITH VISTA

R.A. Penfold

The friendly and practical approach of this book will help newcomers to digital photography and computing to easily learn the basics they will need when using a digital camera with a laptop or desktop PC. It is assumed that your PC uses Windows Vista, however, if it is a Windows XP machine the vast majority of this book will still apply. The book is written in plain English, avoiding technical jargon and all illustrations are in full colour. It is suitable for all age groups from youngsters to the older generation.

Among the many topics explained are how to: Understand the basic features of a digital camera. Transfer photographs from your digital camera to your computer. View your photographs. Save, sort and file your photographs. Manipulate, crop and carry out simple corrections to your photographs. Copy your photographs on to CD or DVD. Print your photographs. Share images with family and friends anywhere in the world by email or with an online album.

This book will help you quickly get to grips with, gain confidence and expand your horizons in the fascinating hobby of digital photography.

Printed in full colour on high quality non-reflective paper.

120 pages **Order code BP700** **£8.49**

COMPUTING & PROJECT BUILDING

eBAY – TWEAKS, TIPS AND TRICKS

NEW

R. A. Penfold

Online auction sites are one of the most popular types of site on the internet, and the most popular of these is the eBay site. On eBay you can buy and sell practically anything at surprisingly low cost, and all from the comfort of your armchair!

This book contains numerous tweaks, tips and tricks covering various aspects of buying and selling on eBay. These tweaks, tips and tricks will help both new and more experienced users of the site to make the most of eBay's facilities while remaining safe and secure.

Among the many topics covered are: Finding the items you require using the eBay search facility: Getting the best prices when buying and selling on eBay: Avoiding both buying and selling scams: Determining the market value for items you intend buying or selling: How to avoid problems that may arise when buying and selling on eBay: Making the most of the various facilities that are built into the eBay site: How to take good photos of items you wish to sell using basic equipment: Using the My eBay page to stay in control of your buying and selling activities: And more besides.

128 pages **Order code BP716** **£7.50**

THE INTERNET – TWEAKS, TIPS AND TRICKS

NEW

R. A. Penfold

Robert uses his vast knowledge and experience in computing to provide you with useful hints, tips and warnings about possible difficulties and pitfalls when using the Internet. This book should enable you to get more from the Internet and to discover ways and means of using it that you may not have previously realised.

Among the many topics covered are: Choosing a suitable browser: Getting awkward pages to display properly: Using Java, spell checkers and other add-ons: Using proxy servers to surf anonymously and privacy facilities so you do not leave a trail of sites visited. Ways of finding recently visited sites you can no longer find: Using download managers to speed up downloads from slow servers. Plus, effective ways and tricks of using search engines to locate relevant info: Tricks and tips on finding the best price for goods and services: Not getting "conned" when buying or selling on eBay: Finding free software: Finding and using the increasing range of Cloud computing services: Tips on selecting the best security settings: Etc,etc,etc.

128 pages **Order code BP721** **£7.50**

FREE DOWNLOADS TO PEP-UP AND PROTECT YOUR PCS

NEW

R. A. Penfold

Robert uses his vast knowledge and experience in computing to guide the reader simply through the process of finding reliable sites and sources of free software that will help optimise the performance and protect their computer against most types of malicious attack.

Among the many topics covered are: Using Windows 7 optimisation wizard: Using Pitstop for advice on improving performance, reducing start up times, etc: Free optimisation scans and the possibility of these being used as a ploy to attack your PC.

Plus, free programs such as Ccleaner, Registry checker and PCPal optimisation software: Internet speed testing sites and download managers: Overclocking sites together with warnings about using this technique: Sites and software for diagnosis of hardware faults, including scanning for out of date drivers and finding suitable replacements: Free Antivirus software and programs that combat specific types of malware: Firewalls: Search engines to identify mystery processes listed in Windows Task Manager.

128 pages **Order code BP722** **£7.50**

HOW TO BUILD A COMPUTER

R.A. Penfold

To build your own computer is, actually, quite easy and does not require any special tools or skills. In fact, all that it requires is a screwdriver, pliers and some small spanners rather than a soldering iron! The parts required to build a computer are freely available and relatively inexpensive.

Obviously, a little technical knowledge is needed in order to buy the most suitable components, to connect everything together correctly and to set up the finished PC ready for use. This book will take you step-by-step through all the necessary procedures and is written in an easy to understand way. The latest hardware components are covered as is installing the Windows Vista operating system and troubleshooting.

320 pages **Order code BP591** **£8.99**

BUILDING VALVE AMPLIFIERS

Morgan Jones

The practical guide to building, modifying, fault-finding and repairing valve amplifiers. A hands-on approach to valve electronics – classic and modern – with a minimum of theory. Planning, fault-finding, and testing are each illustrated by step-by-step examples.

A unique hands-on guide for anyone working with valve (tube in USA) audio equipment – as an electronics experimenter, audiophile or audio engineer.

Particular attention has been paid to answering questions commonly asked by newcomers to the world of the vacuum tube, whether audio enthusiasts tackling their first build, or more experienced amplifier designers seeking to learn the ropes of working with valves. The practical side of this book is reinforced by numerous clear illustrations throughout.

368 pages **Order code NE40** **£29.00**

PRACTICAL FIBRE-OPTIC PROJECTS

R. A. Penfold

While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.

The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.

All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.

132 pages **Order code BP374** **£5.45**

BOOK ORDERING DETAILS

All prices include UK postage. for postage to Europe (air) and the rest of the world (surface) please add £2 per book. For the rest of the world airmail add £3 per book. **Note: Overseas surface mail postage can take up to 10 weeks**. CD-ROM prices include VAT and/or postage to anywhere in the world. Send a PO, cheque, international money order (£ sterling only) made payable to **Direct Book Service** or card details, Visa, Mastercard or Maestro to:

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For a further selection of books see the next two issues of *EPE*.
Tel 01202 880299 Fax 01202 843233. Email: dbs@wimborne.co.uk
Order from our online shop at: www.epemag.com. Go to the 'UK store'.

COMPUTING AND ROBOTICS

NEWNES INTERFACING COMPANION

Tony Fischer-Cripps

A uniquely concise and practical guide to the hardware, applications and design issues involved in computer interfacing and the use of transducers and instrumentation.

Newnes Interfacing Companion presents the essential information needed to design a PC-based interfacing system from the selection of suitable transducers, to collection of data, and the appropriate signal processing and conditioning.

Contents: Part 1 – Transducers; Measurement systems; Temperature; Light; Position and motion; Force, pressure and flow. Part 2 – Interfacing; Number systems; Computer architecture; Assembly language; Interfacing; A to D and D to A conversions; Data communications; Programmable logic controllers; Data acquisition project. Part 3 – Signal processing; Transfer function; Active filters; Instrumentation amplifier; Noise; Digital signal processing.

295 pages **Order code NE38** **£41.00**

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PCB SERVICE

CHECK US OUT ON THE WEB

Printed circuit boards for most recent *EPE* constructional projects are available from the *PCB Service*, see list. These are fabricated in glass fibre, and are fully drilled and roller tinned. Double-sided boards are **NOT plated through hole** and will require 'vias' and some components soldering to both sides. All prices include VAT and postage and packing. Add £2 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Tel: 01202 880299; Fax 01202 843233; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.com**. Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only)**.

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail. Back numbers or photocopies of articles are available if required – see the Back Issues page for details. WE DO NOT SUPPLY KITS OR COMPONENTS FOR OUR PROJECTS.

Please check price and availability in the latest issue. A large number of older boards are listed on, and can be ordered from, our website.

Boards can only be supplied on a payment with order basis.

PROJECT TITLE	ORDER CODE		COST
JUNE '11			
230V AC 10A Full-Wave Motor Speed Controller	804		£10.69
Precision 10V DC Voltage Reference	805		£7.77
6-Digit GPS Clock Driver (Pt.2)	806		£8.16
Musicolour IRDA Accessory	807		£7.38
JULY '11			
Beam-Break Flash Trigger – IR Source	808	pair	£9.72
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Metal Locator	810		£8.56
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Next Month

Content may be subject to change

Ultrasonic anti-fouling for boats – Part 1

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Designing and installing a hearing loop for the deaf – Part 1

Many people have hearing impairment. Whether they are watching TV, listening to radio, or attending a concert, meeting or religious service, they have difficulty hearing what is going on – even with a hearing aid. This article looks at hearing loops, which inductively couple an audio signal to a hearing aid.

T
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Hearing loop receiver

This receiver is designed to pick up the signal from a hearing loop and will drive a pair of headphones. You can use it with a hearing loop you install in your own home or with commercial loops already installed in halls, theatres and meeting places.

Electrolytic capacitor reformer and tester – Part 2

In the current issue, we introduced our new electrolytic capacitor reformer and tester – ideal for anyone working with vintage radios, valve equipment or indeed the hobbyist who has gathered a collection of electrolytics over the years. In September's *EPE* we show you how to construct, test and use this handy piece of kit.

Jump Start

Protect your property with this simple alarm circuit! Mike and Richard Tooley build a 'Theft Alarm', the fifth project in our special series dedicated to newcomers, or those following courses taught in schools and colleges.

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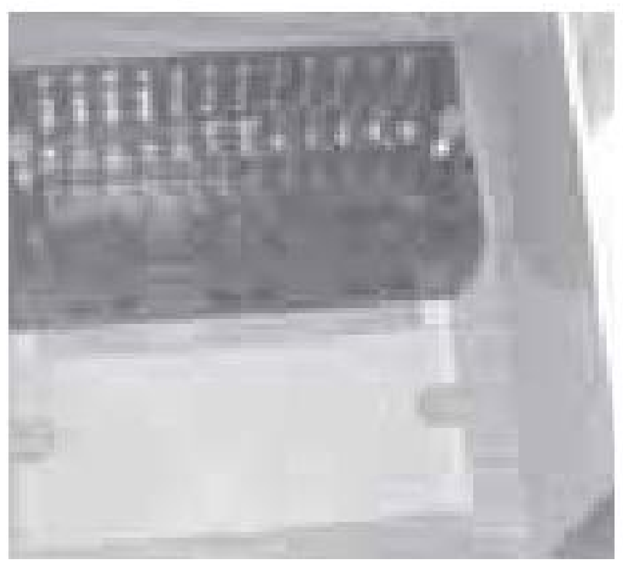

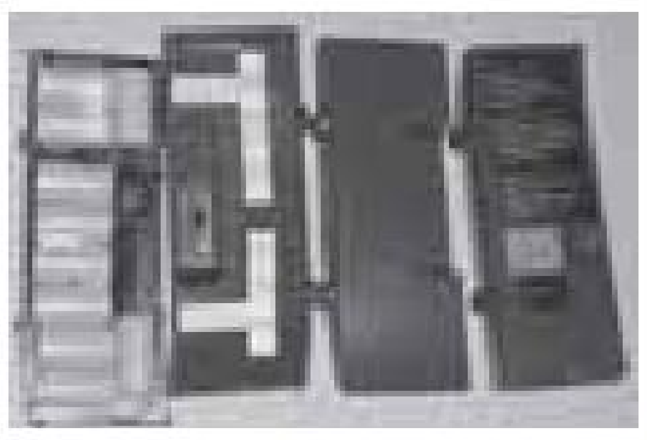

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